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BRITISH WELDING JOURNAL

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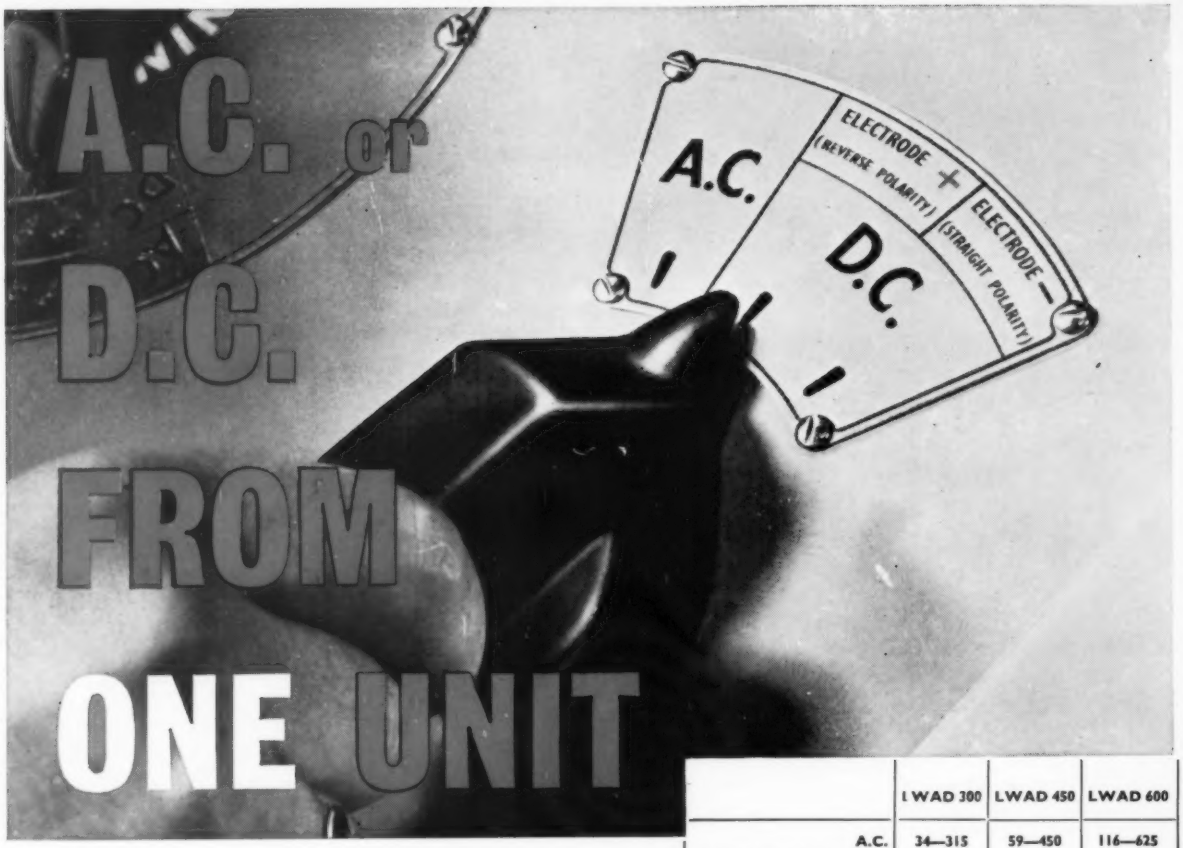

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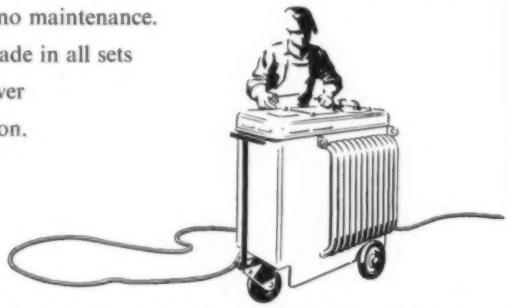

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Inside front cover

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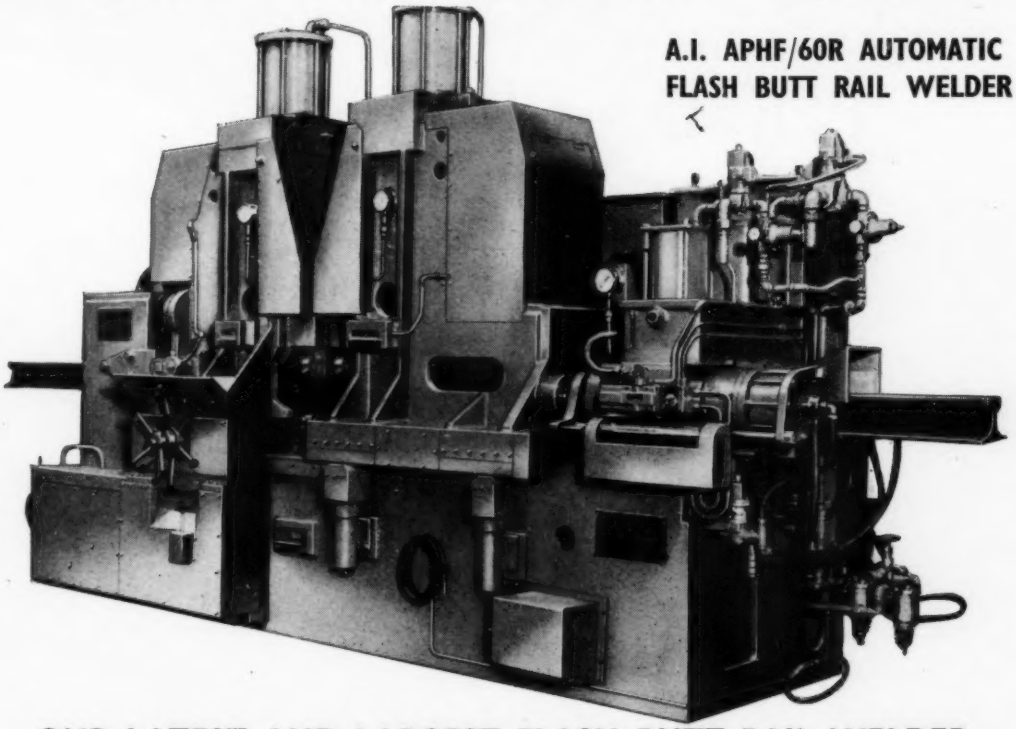

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TO THE SHORE OF THE PERSIAN GULF...

The team used 'Kodachrome' 35mm film to provide a permanent record in colour of this very difficult pipe-laying job. This picture is from part of a 35mm 'Kodachrome' transparency. Courtesy of Metal and Pipeline Endurance Limited.

Some of the most rugged terrain a pipe-laying team could possibly encounter faced C.J.B. and Williams Brothers' engineers when they started work for Iranian Oil Exploration and Producing Company on the 71-mile pipeline from Gach Saran to Ganaveh on the shore of the Persian Gulf. The route takes them up and down mountain sides, over craggy outcrops, through shifting sands.

The pipe itself will be subjected to heavy and varying strains. The welded joints have to be made absolutely safe. And *proved* safe. So from Metal and Pipeline Endurance Limited (MAPEL) inspectors were called in tc check the quality of the welding.

In situations such as this, where the conditions of laying and inspecting are as difficult as nature can make them, the inspection team demands a high standard of efficiency and performance in the equipment and materials it uses.

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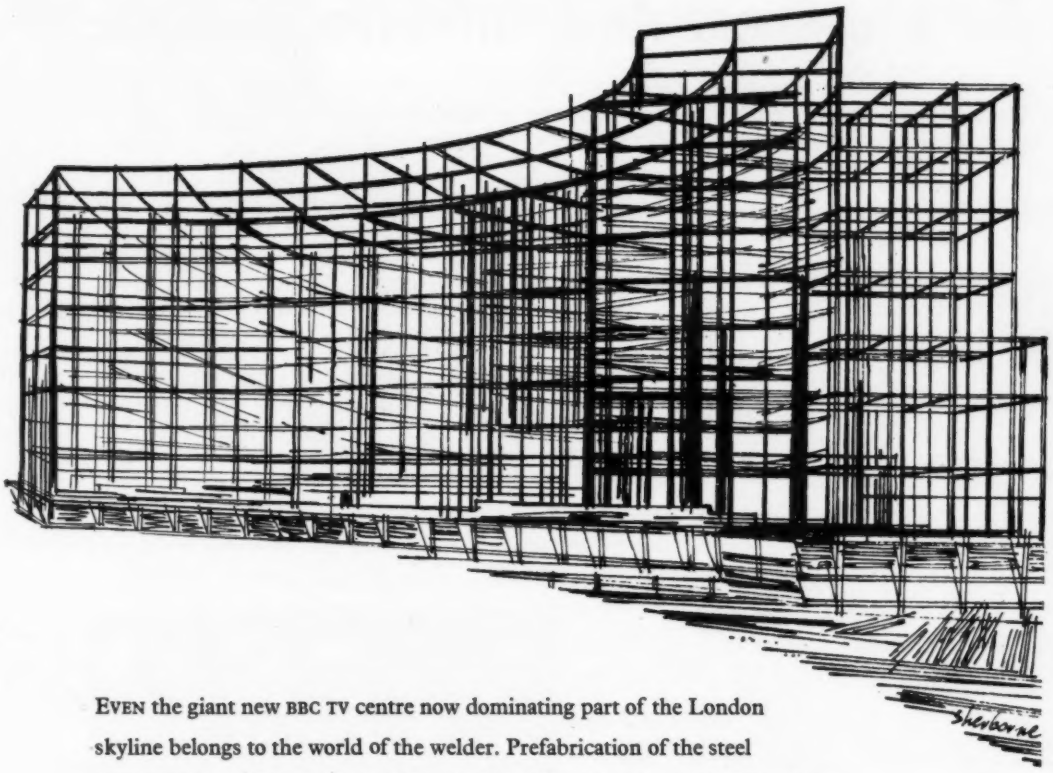

EVEN the giant new BBC TV centre now dominating part of the London skyline belongs to the world of the welder. Prefabrication of the steel framework, by Messrs. T. C. Jones & Co. Ltd., of London and Treorchy, for this remarkable building was made possible by welding – with AEI electrodes.

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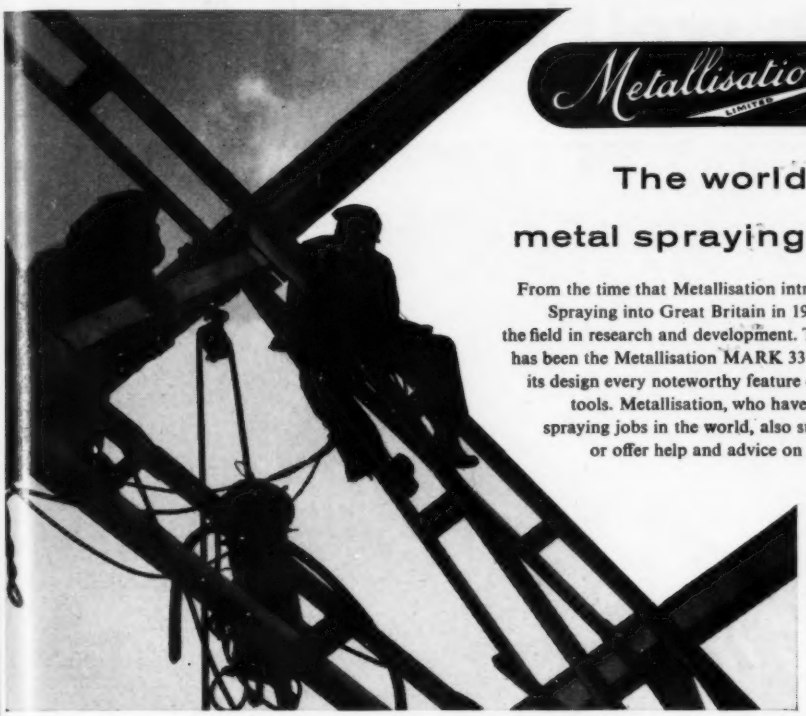

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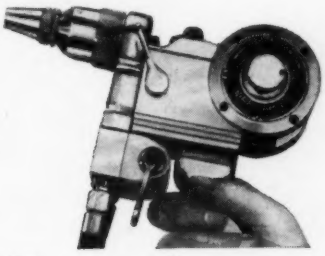

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Subject IGNITRONS — RATINGS

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Types	Maximum Demand* (kVA)	Maximum average* anode current (Amps.)	Temperature control
BK 22	450	15	—
BK 24	1200	140	—
BK 24A	1200	140	Integral
BK 24B	1200	140	Clamp on
BK 34	2400	355	—
BK 34A	2400	355	Integral
BK 34B	2400	355	Clamp on
BK 42	600	56	—
BK 42A	600	56	Integral
BK 42B	600	56	Clamp on
BK 66	300	22·4	—

* Ratings are for welder control service, with two valves in inverse parallel at any voltage from 250-600v. r.m.s.

Rectifier types

Type	Maximum peak voltage (Kilo volts)	Maximum average current at peak voltage (Amps.)
BK 44	2·1	75
BK 46	2·1	150
BK 56 †	20·1	150

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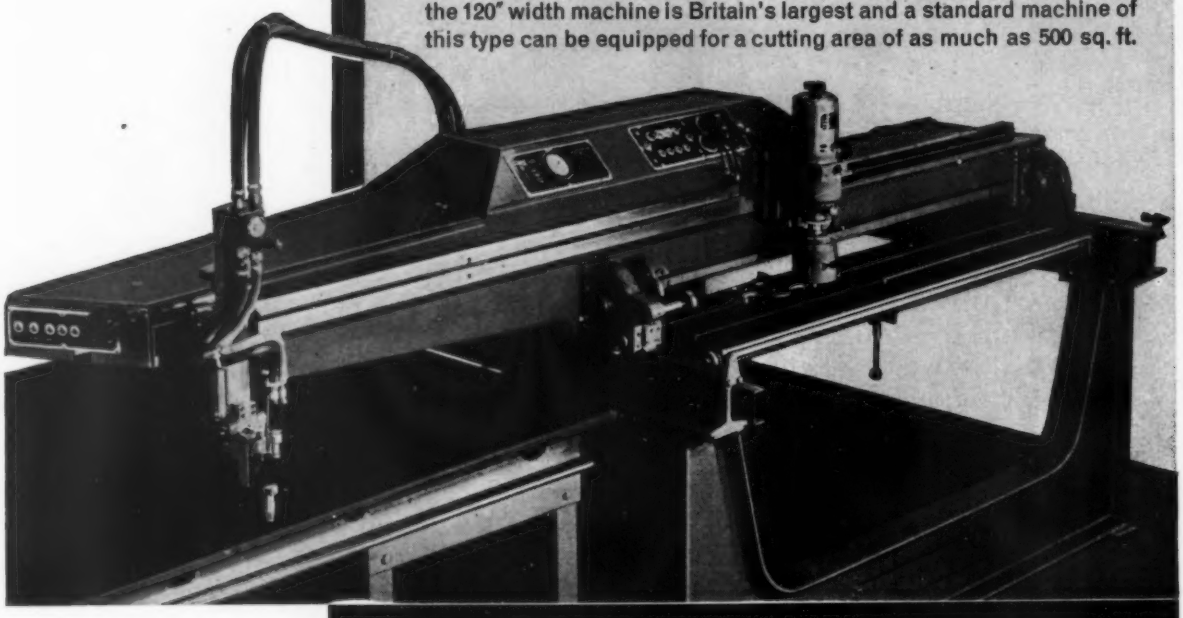

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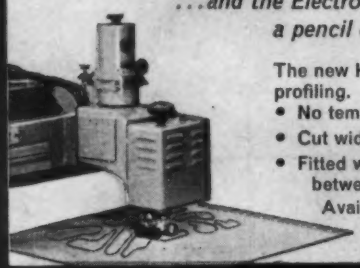

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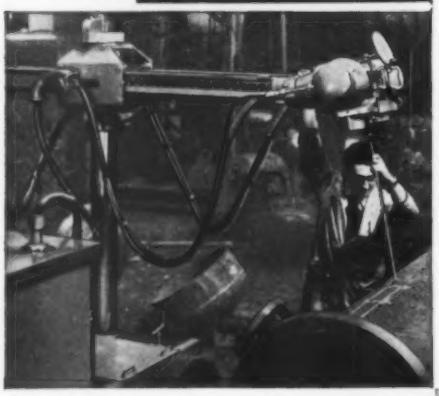

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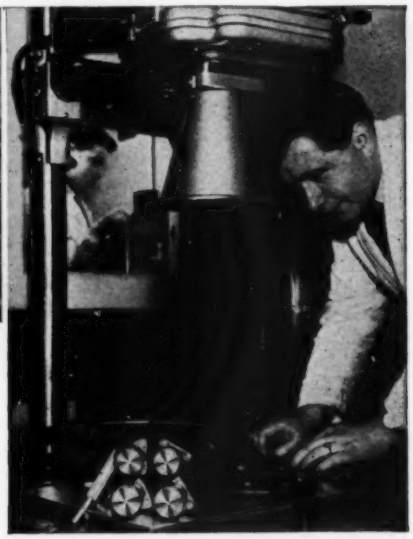

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IX15

interlas

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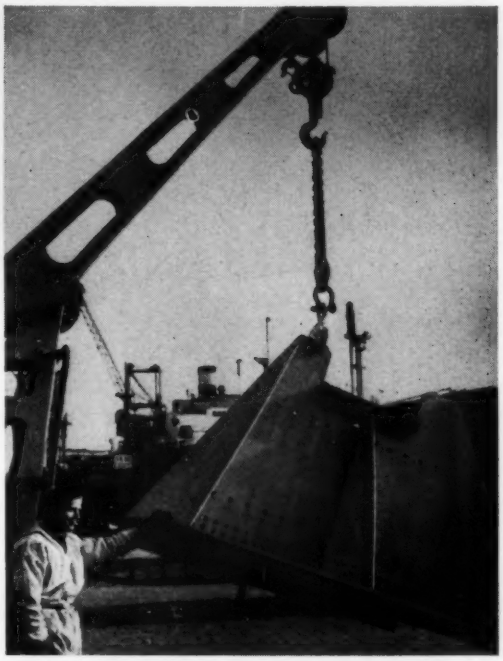
Illustration below shows INTERLAS Lifting Clamp handling a fabricated section in a shipyard.



INTERLAS Lifting Clamps have been specially designed to ensure absolute safety as well as speed in the lifting and transporting of steel plates.
When the load becomes greater the gripping power increases, as it is twice the tensile force, i.e. when lifting a plate weighing 3 tons the gripping power is about 6 tons. Yet the plate can be rested on the ground and laid on its side without fear of the clamp slipping, as the jaws do not release their grip until the locking lever has been released.
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They cost a little more than ordinary lifting clamps, but they are cheaper in the long run.

Model	Lifting Capacity	Std. Jaw Opening	Special Jaw Opening
1½ TS	1½ tons	0—¾″	¾″—1½″
3 TS	3 tons	0—1″	1″—2″
6 TS	6 tons	0—1¼″	1″—2¼″
9 TS	9 tons	0—1½″	1″—2½″
12 TS	12 tons	0—1¾″	1″—2½″
15 TS	15 tons	0—2¼″	3″—6″
20 TS	20 tons	0—3″	3″—6″

★ *lift quickly and safely*

★ *can be fastened with plates in any position*

★ *cannot work loose even when subjected to heavy shocks*

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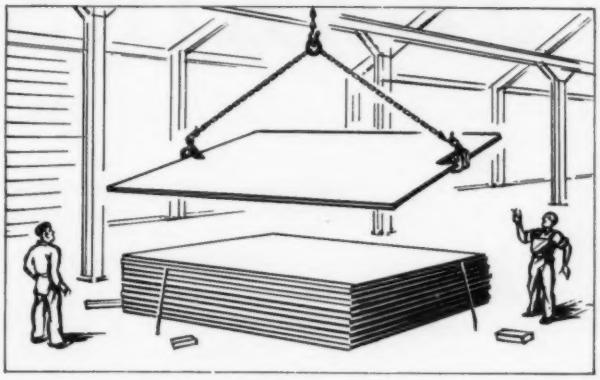
MODEL	LIFTING CAPACITY PER PAIR	JAW OPENING
1½TH	1½ tons	0—2¼″
3 TH	3 tons	0—2¼″
4 TH	4 tons	0—2¼″
6 TH	6 tons	0—2¼″
8 TH	8 tons	0—2¼″



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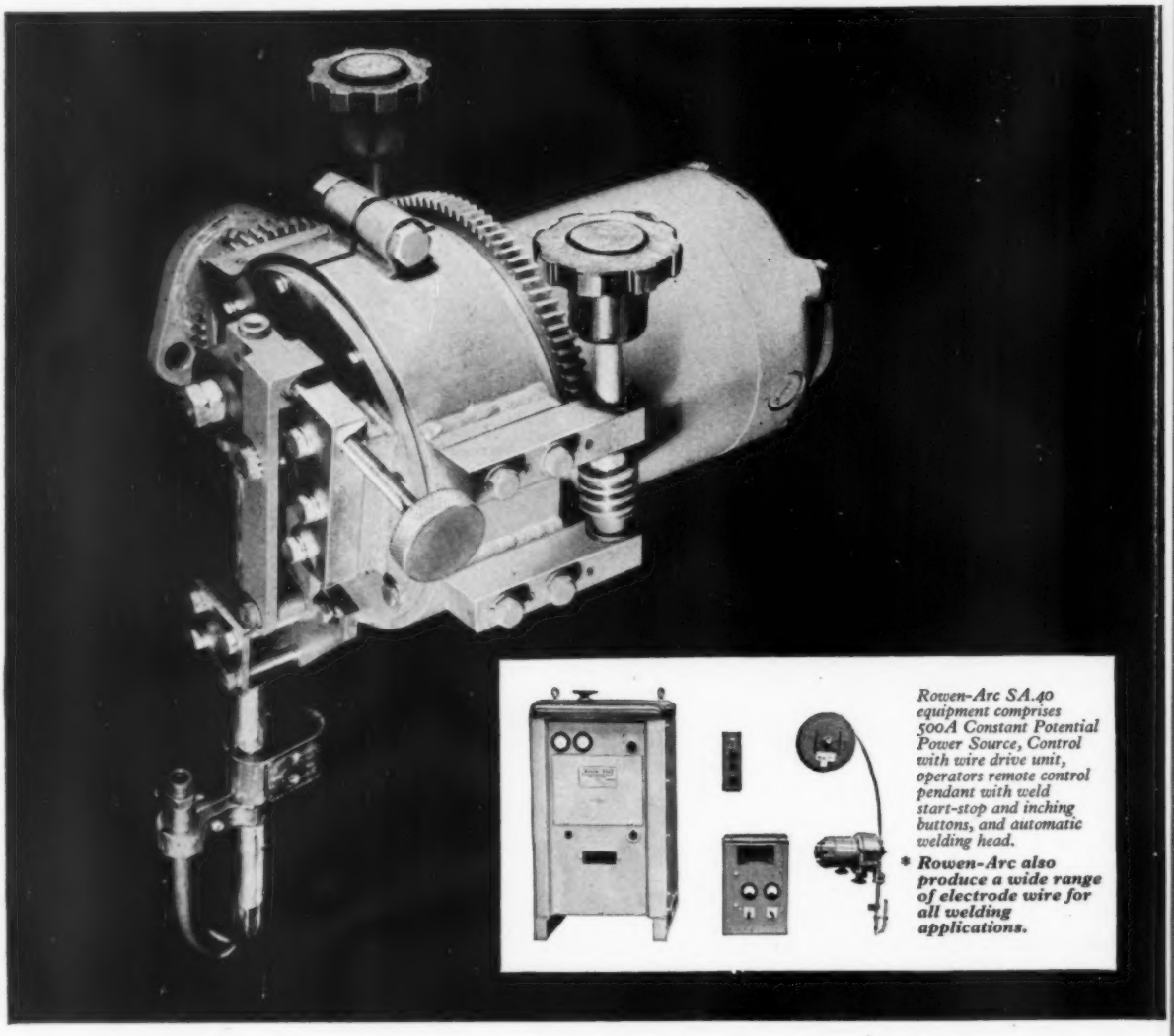

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Welding TECHNOLOGY

Lloyd's Register Requirements in the Testing of Welders

By F. B. Bowring

By reason of the origin, growth, and subsequent constitution of Lloyd's Register, its philosophy in regard to technical decisions is somewhat different from the approach made by the survey departments of the industrial Insurance Companies.

The Society's requirements for the qualifications of welding operators is briefly explained. These requirements are under constant review and are subject to revision according to needs.

Although the Society's requirements cannot be presented concretely at the present time, the author describes the background and approach to certain cases.

BEFORE Lloyd's requirements for the testing of welders are discussed it is advantageous to give some idea of the philosophy that lies behind the Society's approach to the problem, with particular emphasis on Land work, although the broad basis of these requirements will obviously refer also to Marine work.

The origins of Lloyd's Register of Shipping are the same as those of the world-renowned "Lloyd's of London" whose correct title is "The Corporation of Lloyd's", although the two organizations are now kept separate.

In the 1680's, Mr. Edward Lloyd, who was the proprietor of a coffee shop in the City of London, near Tower Hill, noticed that his clientele included many persons connected with shipping. He encouraged this fraternity, and by the turn of the century was issuing, three times a week, his own newsletter which specialized in shipping intelligence.

The coffee-house did not become the centre of underwriting until about twenty years later, by which time Edward Lloyd had died, but his name continued and the coffee-house prospered.

Lloyd's Register itself was not founded until 1760, for the purpose of classification of ships. At that time it was under the management of the underwriters alone, perhaps in rather the same way as insurance companies at the present time have their own survey departments directly answerable to the companies themselves. In the course of time, the ship-owners who frequented Lloyd's became dissatisfied with the system of classification adopted by the underwriters' Registry and, as a result, set up their own Registry of Ships with its own attendant survey department. This unhappy state of affairs could not last for long and, in 1834, the ship-owners and underwriters came to a better understanding with each other and Lloyd's Register of Shipping, as we know it today, was constituted.

The Society of Lloyd's Register of Shipping is a voluntary association of underwriters, ship-owners, and ship and engine builders, each having an equal share in its management. It is a technical body and is not a commercial concern with profit as its motive. In all essentials it is, in fact, a Public Body, which, having no shareholders, has no interests to serve beyond those

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Mr. Bowring is in the Land Division of Lloyd's Register of Shipping.

of supplying technical service so that a balance is attained between what is technically desirable and what is economically possible.

The whole of the Society's revenue is devoted to perfecting its organization and maintaining and extending the sphere of its usefulness throughout the world, for it is an international organization.

The outlook of the Society can usefully be illustrated by the remark of one of its Senior Technical Officials in regard to a rather unknown welding technique. He told the inquirer that Lloyd's Register would be quite happy for the manufacturers to use cardboard electrodes if it could be proved to Lloyd's satisfaction that such electrodes consistently gave good results which could be accepted by the Society. This example, whilst it does show the Society's philosophy is, of course, somewhat exaggerated, in that when it is thought that a manufacturer is endeavouring to embark on a technique that is considered to be fundamentally unsound, there is no hesitation in telling him so.

The application of this philosophy to welding matters can best be illustrated by actual examples of work with which the Society has been concerned. These include the building of the larger reactor vessels intended for the present type of nuclear power plant such as the installations at Berkeley, Bradwell, Hunterston, and more recently, the Latina Station in Italy. These vessels are some 50–60 ft in diameter and with wall thicknesses of 3–4 in. they bristle with difficulties, but the problems are basically the same.

At the start of a contract of this nature, the manufacturer is expected and, in fact, is requested to produce a comprehensive and detailed welding procedure. This is examined and commented on in the Society's London Office.

The welding procedure is then proved by actual tests, which may be done in the manufacturer's own works and by any welders they like to choose, but the conditions must simulate the actual conditions of construction. In this connection it should be mentioned that many vessels are, in fact, part-built in the shops and part on the site.

The Society has, in the past, insisted that four positions of welding must be carried out to represent a site-welded vessel of the type considered.* These are:

(*a*) Vertical
(*b*) Horizontal
(*c*) 45° vertical, *i.e.*, semi-vertical, semi-downhand
(*d*) Overhead and downhand.

Naturally, the test plates are large when 3 in. or 4 in. thick plate is being welded, and all the usual tests, including radiographic examination, are taken from these test plates as required by the accepted Codes, such as BS.1500, "Lloyd's Rules for Welded Pressure Vessels", and the like. In addition, Charpy impact specimens are taken from the weld metal and fusion zone, because:

(i) Notch tough weld metal is required for site constructed vessels, and
(ii) Neutron bombardment is known to lower the notch toughness of mild steels.

For these reasons the steel must have a rather better than normal degree of notch toughness.

It is also usual to take a hardness traverse across the weld, with 250 D.P.N. as the normally accepted maximum and with a differential of not more than 90 D.P.N.

The proposed welding procedure must also be proved in two further important ways, which are inter-related. The first covers restraint, and the second the number of repairs that can be satisfactorily carried out before there is serious difficulty with cracking, etc.

On large structures there can be very severe restraint when welding, although naturally the contractor will endeavour to minimize it. A test plate is welded in the 45° horizontal position in such a way that the plates are given the least possible freedom of movement.* To prove the second feature, in regard to repairs, the completed test plate is first chipped out and repaired on one side and then on the other side. This procedure is repeated three or four times. It should be remarked, however, that although these repair tests are repeated in this way, the Society still considers that it is most important that any repair should be correctly carried out at the first attempt. For instance, it is insisted that proper precautions are taken to ensure that the weld is cut at the right place, and that in fact all the defective area has been cut out before welding up is commenced.

The technique of radiographic examination is something that vitally concerns the welders. The Society specifies that such techniques shall be the best possible for the actual work being undertaken. Although this normally means X-rays, the Society permits the use of gamma rays where this is the best technique for the particular job; but it must be emphasized that the type of gamma ray source has to be approved for the job.

The author is unaware of the use of caesium 137 being permitted in any job for which he has been responsible. Iridium 192 has been accepted on quite a number of contracts for thicknesses varying from $\frac{1}{4}$–$1\frac{1}{2}$ in., and recently, on one particular contract, the new very powerful cobalt 60 sources (1500 curies) have been approved for use on $4\frac{3}{8}$ in. plate.

In addition to its use in checking the soundness of welds, radiography most certainly has a psychological effect on welders themselves; there are many instances of welders taking a really intelligent interest in radiographs of their welds in an effort to improve and maintain their work. The radiographic standard required for welds in this class of work is very high. In fact, at the start of a job, it is very difficult for this standard to be too high, for it is always easy to relax the standard at a later stage if it is considered justifiable but it is very difficult indeed to raise the standard once the job is under way.

After the welding procedure has been proved and found satisfactory, it is necessary to test the individual welders; it is invariably insisted that this should be done at the location of construction, be it shop or site. This has been found particularly necessary for site work for several reasons, not the least of which is that it gives a welder a good opportunity to "fluff" his test

* For details, reference should be made to Appendix IV of Lloyd's Register of Shipping Land Division "Provisional Requirements for the Survey of Pressure Components for Land Based Nuclear Installations."

if he has decided that he has no wish to remain on the site. This may sound far-fetched, but there are instances where a perfectly good welder has decided that he wants to leave the site—rather than saying so outright, he has preferred to do bad work or bad tests.

The tests taken are usually again in the four positions mentioned previously; except, as does happen now and then, when a welder is to be used only for a certain specific position and qualifies only for that position.*

These operator qualification test plates are kept as simple as possible and, normally, they are required to pass only radiographic examination, together with face and reverse bend tests and a macro examination. Sometimes the fabricator himself takes additional tests for his own benefit, but these are not requirements. It is stressed that these qualification tests are taken and the results approved before the welder is allowed to commence work on the site.

With the welding procedure proved and the operators having passed their tests, fabrication can start on the site. But routine tests and further operator tests are required during construction. These routine tests take the place of the normal coupon plates attached to the ends of the longitudinal seams of a shop fabricated vessel; they are taken as construction proceeds and they cover the different welding positions found in the vessel. Again, these have to be quite large test plates, because immediately on completion, and after X-ray, the plates are cut in half, and one half is immediately furnace stress relieved and tested in the same way as the welding procedure was proved. The other half is kept until the vessel is completed, and is stress relieved with the vessel so that the test plates can be used for the official certification of the vessel. It is probable that up to 25 such test plates would be required for a vessel 50 ft dia. and 80 ft high. The choice of the welder to undertake each test plate is by agreement with the resident Lloyd's Surveyor, and each test plate is welded under the same conditions as the welder would be working on the job; *i.e.*, if he is working on a vertical seam 60 ft above ground level, the test plates would be set-up at that level and welded there. An attempt is made for each welder to supply one official test plate for the vessel before completion, but this is not always practicable because:

(*a*) It is becoming common practice to use teams of up to 40 or 50 welders on a vessel, and it is not considered that so many official test plates need be made even for these large pressure vessels

(*b*) It is a very good thing to test a welder at a fairly early stage after he has started on the job, as a guard against his leaving without any actual tests being available.

So far, only the tests required for the welding operatives before and during construction of the shell have been considered, and attention must now be given to the requirements for the welding-in of stubs, nozzles, and the like. Essentially, these requirements are the same as those for welding plate; the procedure is first proved, although is it not possible to take tensiles and bends, nor it is usually possible to take radiographs—in fact, acceptance or rejection is largely determined by taking sections through the completed prototype and macro-examination is made for cracks, porosity, slag inclusions, etc. In regard to operator tests for this rather intricate work, it is quite obvious that only a few specially selected welders can be used, who are known to be particularly adept at working in awkward places. But welders who have passed their tests in the four positions previously mentioned are quite capable of doing this work, and it is not normally required that each welder should make a mock-up test for sectioning. Tests carried out during the welding of stubs, nozzles, and so on, into the actual vessel, do not come within the scope of this paper and will not therefore be dealt with.

It has already been stated that the Society insists on testing welders in four positions—vertical, horizontal, 45° vertical, and overhead-downhand, for this is considered to represent all the main positions in a site-welded vessel. These tests do not, however, give any insight as to what the welder will do at a T junction and, recently, the Society has endeavoured to incorporate this joint into its operator test. If two test plates are welded together and another plate is welded to them across one end this type of joint can be achieved, and at the same time the four positions can be incorporated into one test plate.

The plates are first welded at 30° to the horizontal, back gouged and repositioned vertically for welding the back side.†

There are, however, difficulties in cutting out the necessary specimens without undue waste of material, although it is understood that this T construction of test plates is being carried out for the submarine hull for *Dreadnought* and for the Latina Power Station.

There is another characteristic which, at present, test plates do not cover. It is very easy to line-up and set the gaps correctly for a test plate, but the job itself is seldom so accurate, and a proposal is being considered that the test plates should be welded at the maximum misalignment specified for the work that has been agreed in the welding procedure specification.

So much for the weld tests that welders have to pass before and during the welding of one of these big vessels. It is hoped that these few remarks have provided some "food for thought" and have pointed to the ways and means that can be devised to improve testing so as to give results that more closely represent the conditions in the actual construction.

* Since this paper was written, these requirements have been slightly amended, and those interested should refer to Appendix IV of the Society's Provisional Requirements.

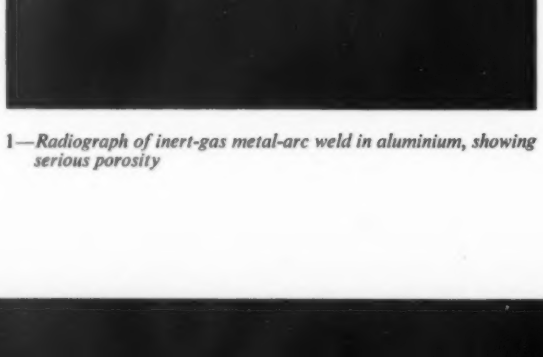
† Details of this test can be found in Appendix IV of the Society's Provisional Requirements.

PRESIDENTIAL ADDRESS

Quality in Welding

By E. Fuchs, M.A., A.M.I.MECH.E.

SOME years ago I read a paper to a number of the Institute's Branches entitled "*The Aim in Welding —One Quality, the Best*". It seems to me, after giving the matter much thought since then, that this must still be our constant aim. The only modification which one might allow oneself is to couple the concept of 'Best Quality' with that of 'Fitness for Purpose'. Whilst the aim before one is perfection, the quality achieved, or often the best quality that can be achieved with available knowledge and means, need only be such as to fit the purpose for which the particular article is intended. The judgement as to the standard required is probably the most difficult task in one's life as an engineer. Just what is good enough? Putting the theme another way, anyone can specify something free from blemishes, but a great deal of knowledge and experience is needed to specify the blemishes that are permissible in an article with a certain duty to perform. Let me give an example from our everyday practice. The butt welds in Class 1 pressure vessels are examined by radiography. It has been proved over many years that, without undue trouble or expense, butt welds of such excellence can be produced in mild steel pressure vessels that radiographs will pick out no faults. Everyone has accepted this situation as completely normal so that, should any faults be detected by radiography, they are removed by manufacturers of Class 1 mild steel pressure vessels without further consideration.

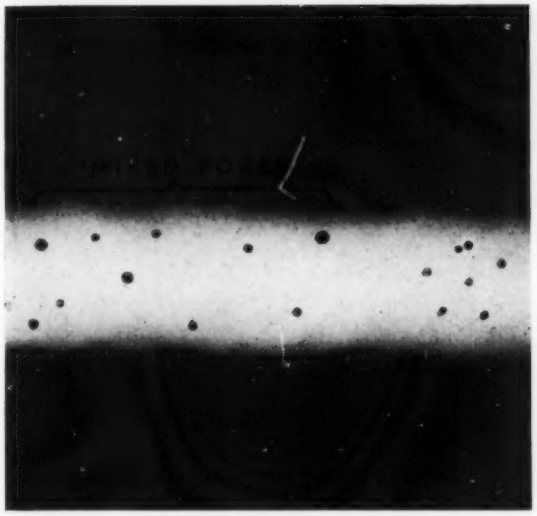


1—*Radiograph of inert-gas metal-arc weld in aluminium, showing serious porosity*

We come now to pressure vessels in aluminium and its alloys. Here, it has been established that with the processes so far available, especially with the fast and economical inert-gas metal-arc method, complete freedom from porosity in the welds simply cannot be guaranteed, so that it is useless to specify clear radiographs, however onerous the duty for which the vessel is intended. Careful investigation has shown that a good workshop with sound supervision can produce welds containing only a small amount of scattered porosity, but with occasional small pools of more concentrated groups of pores, generally at re-starts. It has also been realized that the repair of welds by removing faulty weld metal and rewelding will of itself generally result in a somewhat porous weld. The standard set for Class 1 butt welds in aluminium has, therefore, to allow a defined amount of scattered porosity and pools of more concentrated pores up to the amount that cannot be reduced by repair. In Fig. 1 is shown the serious porosity which may occur in an aluminium weld made by the inert-gas metal-arc process if wrongly operated, whilst in Fig. 2 an attempt has been made to illustrate the degree to which the two features have, in my opinion, to be accepted for the present.

Now arises the question, is this good enough? The answer is that, by and large, porosity is a very much less serious fault than are slag and oxide inclusions with their elongated contours or, of course, than cracks. Under static loading porosity will only reduce the load-carrying capacity of a butt weld in proportion to the reduction in the area. In mild steel this virtually never matters, for in this material all fusion welds produced by the normal arc processes have higher yield and ultimate strengths than the wrought parent metal. In aluminium the strength of welds is, at best, that of the annealed material, and pores will weaken them slightly further. Therefore, considering pressure vessels as statically loaded, in general a fair enough assumption, it can be concluded that a so-called 'weld efficiency factor' and the comparatively low stresses still standardized in this country for Class 1 mild steel

This Address was presented at the Autumn General Meeting of the Institute on Tuesday, 1st November 1960.

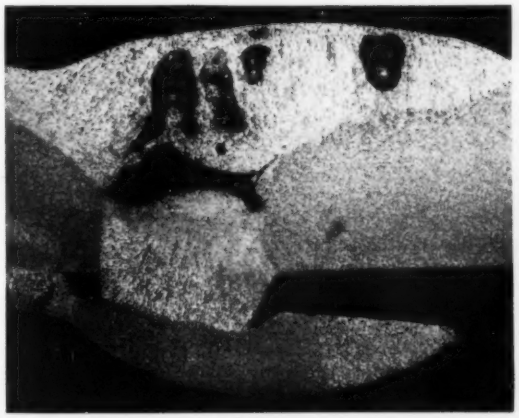


2—*Diagram simulating radiograph with maximum porosity considered acceptable for weld in Class 1 aluminium pressure vessel*

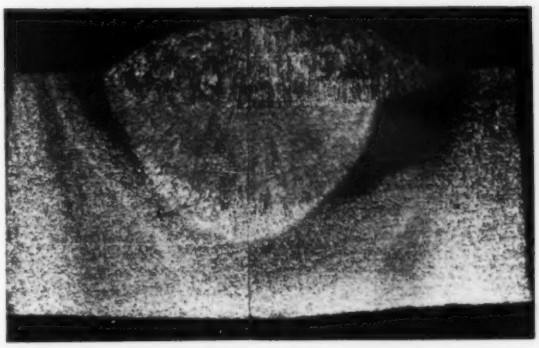
vessels are unjustifiable and their use is out-of-date. For aluminium vessels, on the other hand, there is good reason for allowing only rather conservative design stresses and a weld factor; 95% probably being a realistic figure with the best reasonably achievable radiographic standard. Thus the two concepts of quality and fitness will be suitably matched.

Before leaving the subject of actual weld quality some revealing examples of pipe butt welds warrant consideration. These are illustrated in the recently published B.W.R.A. booklet on pipe fittings.* The committee steering the work summarized in that booklet asked itself years ago what would be the best test to apply to welds for pipelines to assess their quality. Although it was recognized that fluctuating stresses play only a secondary part in properly designed pipelines, it was decided that testing by mechanical or hydraulic pulsations was the surest way of revealing faults that would weaken a pipe system under service conditions. The long series of tests on pipe butt welds showed conclusively that for conditions of alternating bending (incidentally a possible service condition in hot pipelines), evenness of penetration to the bore of the pipe and outside surface condition are the two all-important factors. Thus, an appalling weld (Fig. 3) with sound weld metal only at the surfaces withstood the test as well as some of the sound welds, whereas the solid weld through only two-thirds of the wall thickness (Fig. 4) failed at much lower stress figures. The lesson to be learned here is that the major effort in pipe welding must be concentrated on bore condition, and that faults revealed by radiography in the body of the weld metal can generally be ignored. It would be perfectly sound in thick pipes not to radiograph finished butt welds, but to rely on radiographs of the welds with only enough runs put in to prevent cracking on cooling, a stage at which radiography is already often applied. Subsequently, examination can be restricted to the outside surface and any stress-raising faults can be dressed off.

Since there is such endless controversy on the merits and demerits of backing rings in pipelines, it is worth mentioning that the tests showed that backing-ring welds, properly fused at the root, resisted alternating stresses just as well as soundly penetrated welds without rings. By and large, the backing-ring weld made under properly controlled conditions is probably the most foolproof, but it does not lend itself to proper radiographic or ultrasonic examination and therefore constitutes a cause of dispute between the fabricator, the inspecting authority, and the customer when applied to Class 1 work. It is also unsuitable for many hot-oil duties, where carbon can build up in the slit and disrupt the ring, and for certain applications of austenitic stainless steels where crevice corrosion is a hazard. The right policy would seem to be generally to tighten up inspection during assembly and welding; for instance, by visually examining the internal penetration bead in plain butt welds through the unwelded portion (Fig. 5). The vast amount of radiography and ultrasonic testing now being applied, particularly to unbacked welds, could then be radically reduced yet both types could still be used with confidence.



3—*Pipe weld with gross faults within the weld metal but not at the surfaces*



4—*Partial-penetration pipe butt weld after fatigue test to destruction*

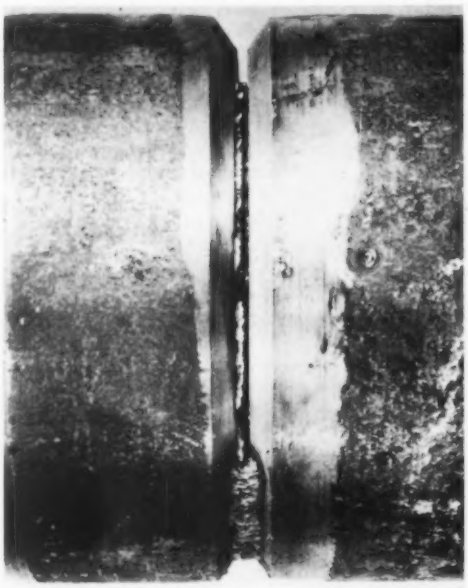
* P. H. R. LANE and R. T. ROSE: "The design of welded pipe fittings", pp. 37–43, British Welding Research Association, 1960.

With further improvements in the butt welding of pipes there will be even more reason than already exists for reducing the thickness of almost all the mild steel pipes used in industry. Is it generally realized that most everyday mild steel piping is still being used with screwing and bending allowances on every length? The screwing allowance on pipelines with butt welds, or welded-on flanges, is a complete waste and, in general, so is the bending allowance, for another series of B.W.R.A. tests* showed that the back of a bend is never the most highly stressed area whatever the form of loading on the bend. Why does industry continue to waste these thousands of tons of steel each year?

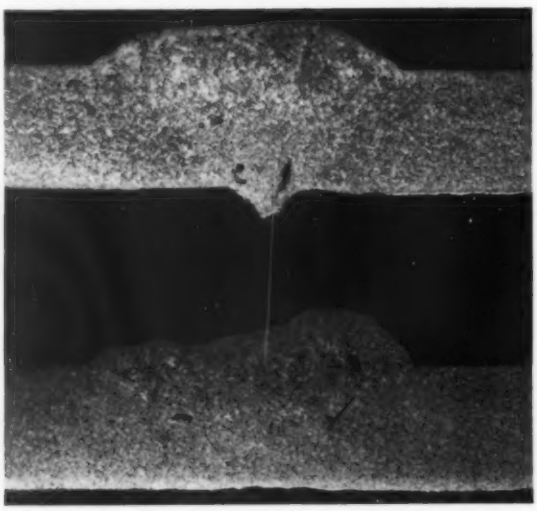
The following two recent examples of pipe butt welding emphasize the need for routine testing if high quality is to be achieved in welding, whether this is done manually or by a machine.

A very good gas welder had settled down to making butt welds by all-position-rightward oxy-acetylene welding in horizontal pipes $\frac{3}{16}$ in. thick. Without changing his manipulation he then welded a tube $\frac{1}{4}$ in. thick on a 45° slope. The result is shown in Fig. 6, with the bend test failure and the fracture appearance shown in Fig. 7. A very slight change in flame and rod manipulation rectified the faults which, without

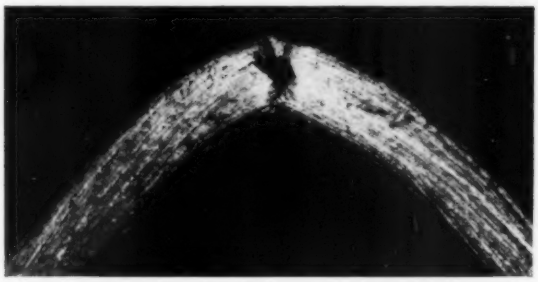
* P. H. R. Lane and R. T. Rose: loc. cit., p.8.

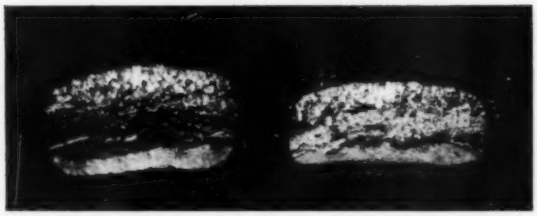


5—Internal penetration bead of pipe butt weld seen through unwelded portion

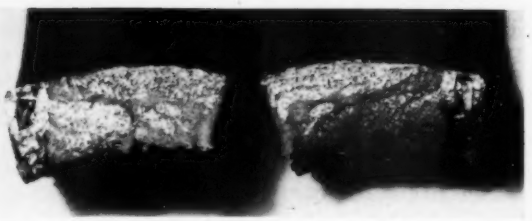


6—Faulty oxy-acetylene weld in boiler tube $\frac{1}{4}$ in. thick

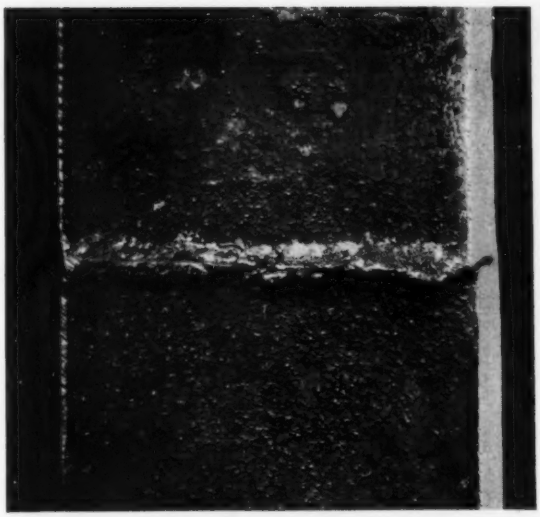




7—Reverse bend test on weld shown in Fig. 6



8—Reverse bend test on faulty flash weld in mild steel tube $4\frac{1}{2}$ in. o.d. × 0·212 in. thick

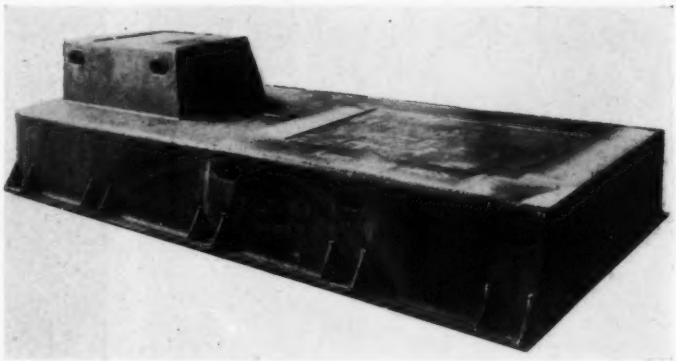


9—*Appearance of internal flash from weld in mild steel tube 4½ in. o.d.×0·212 in. thick*

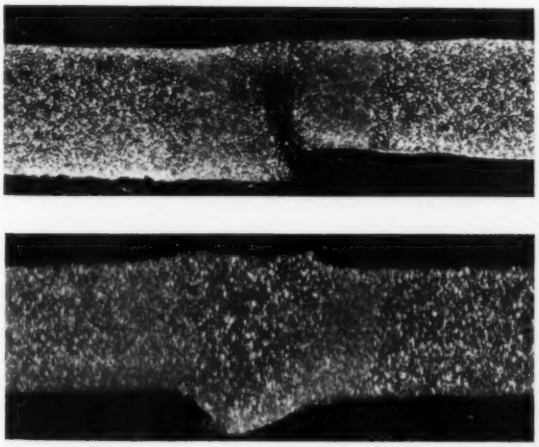
routine testing, would have persisted throughout the pipe system.

In the second instance, a modern flash welding machine had been used to complete some 800 welds in 1½, 2, 3, and 4 in. bore tubes required to be maintenance free in a fairly onerous service. The machine was moved to another site for a similar series of welds, and it was said that the setting for preheat cycles, upset and so on had not been altered. The machine performed as if this was indeed true, and yet bend specimens from the first pre-shift routine test pieces on 4½ in. o.d.× 0·212 in. tubes failed as shown in Fig. 8. The appearance of the internal flash was normal (Fig. 9) but only half the weld was sound, the other half hardly being welded at all. Sections from the two halves are shown in Fig. 10. It was discovered that for transport purposes the moving carriage on the machine had been wound back by the hand control beyond its normal operating position thus bending an internal pin. This pin was a part of the control system, so the true setting had thus been radically altered.

As welding engineers or metallurgists we must be on our toes continuously, or the quality for which we are striving will elude us.



11—*Deep bedplate fabricated by folding and welding*



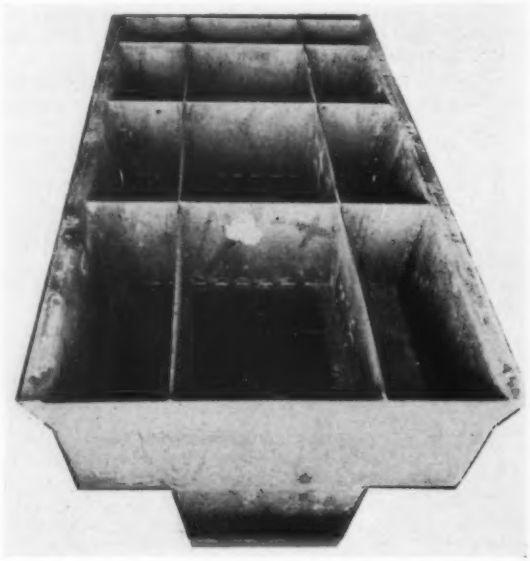
10—*Sections from faulty flash weld in mild steel tube 4½ in. o.d.×0·212 in. thick*

So far I have concentrated on the quality of the weld metal itself, but now let us turn to another aspect which, in my opinion, is of greater and wider interest. I refer to design as the key to fitness for purpose and hence to quality in its widest sense. There are certain fundamental design weaknesses which the experienced engineer recognizes at once—the reaction becomes almost instinctive. Complication is the worst and commonest of them, exemplified by undue amounts of weld metal per ton of product. It is strange how many designers do not realize that weld metal costs between £500 and £1,000 per ton compared with £45 per ton for mild steel plates. The obvious aim is to use the least possible amount of weld metal. In platework this is achieved by the maximum use of folding, the reduction of weld sizes, and the use of intermittent fillet welds wherever the loading permits it and, occasionally, by the use of thicker material to avoid gussetting. Incidentally, the application of any of these principles also reduces distortion and so improves the overall quality of the finished product. Two good examples of

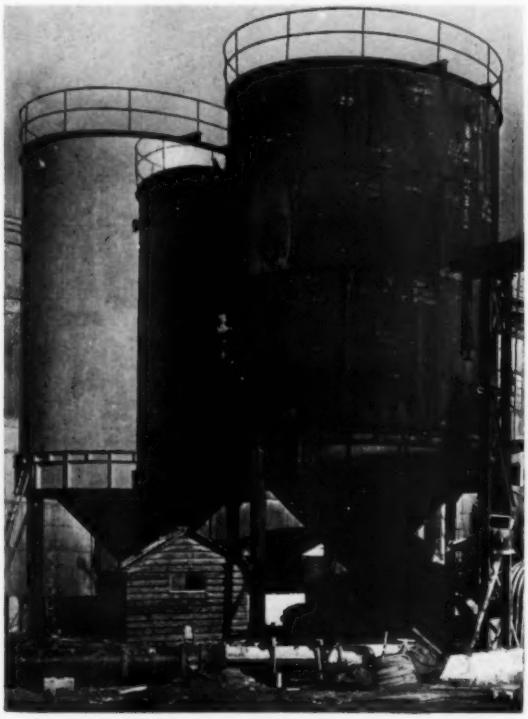
economical fit-for-purpose design are the bedplates illustrated in Figs. 11, 12, and 13. In both these examples folding has been used to eliminate long corner welds, intermittent welds attach the stiffeners, and stiffener material has been used to maximum advantage. In deep sections, box stiffening can be used effectively, but in shallow sections, such as the second bedplate shown, the bogey of cross-wind or diagonal weakness can be mastered only by diagonal bracing. A glance at Fig. 13 will show how easily the cure can be applied.

The tanks in Fig. 14 are another example of true design for welding. The extension of the tank plates below their junction with the cone is suitably stiffened to look after the pull of the cone, often a troublesome force to meet, and to form a wind girder. This girder also neatly distributes the whole tank load over the tubular supports, and these in turn leave ample clearance for pumps and pipework under the cone.

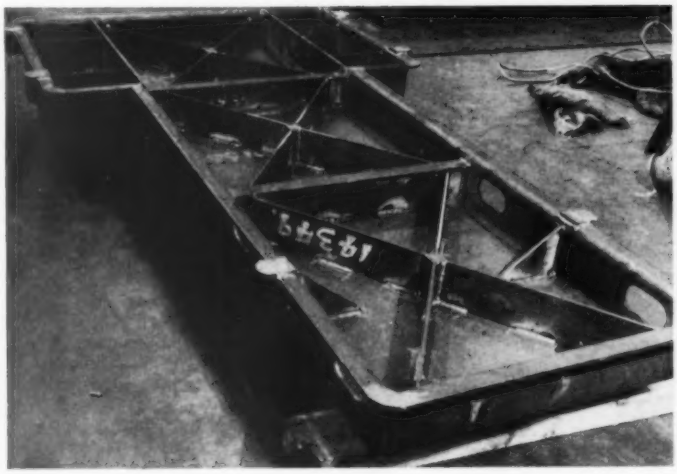
Two last examples of fitness and quality are in the field of steel structures. A store is essentially an area presenting the maximum amount of floorspace and headroom with the minimum interference. Portals ideally provide the solution, as is well illustrated in Fig. 15. These frames were designed with another worthwhile maxim in mind: that, where feasible, welding on site is best avoided. Each stanchion has one-third of its roof member shop-welded to it. The centre two-thirds of the portal forms another shop-welded



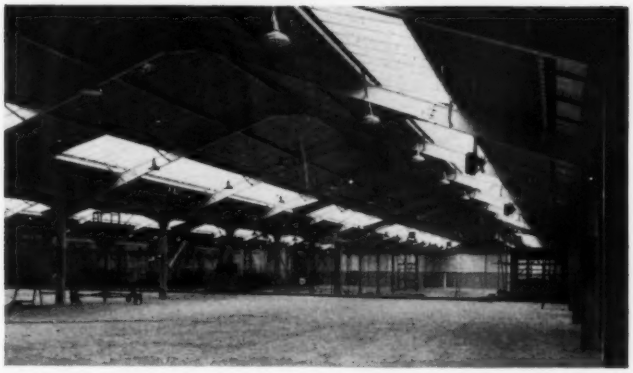
12—*Underside of bedplate shown in Fig. 11 emphasizing box stiffening*



14—*Elevated storage tanks 20-ft dia.*

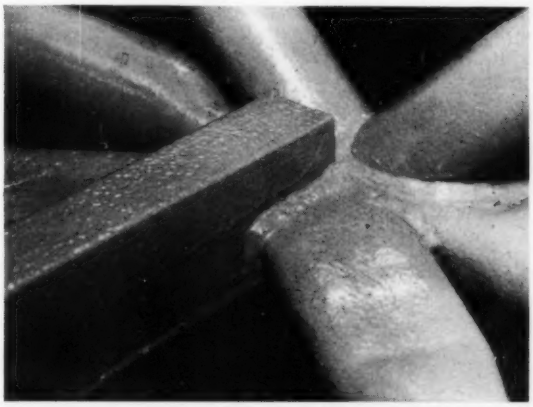


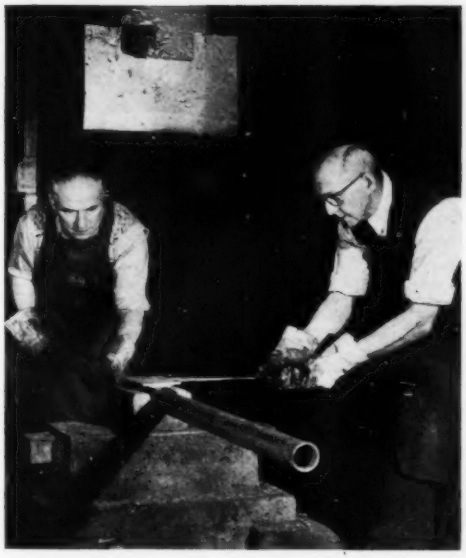
13—*Underside of shallow fabricated bedplate showing diagonal stiffening*



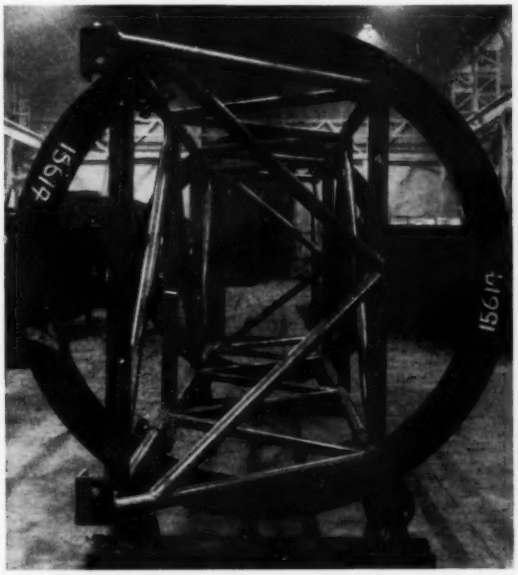
15—*Stores building with unobstructed floorspace*

16—*Complex intersection of tubular structural members*





17—*Producing flat on tubular structural member*



18—*Tubular pipe bridge truss mounted in manipulator for welding*

unit. The resultant pieces are easily transported to site and two simple riveted joints complete each frame.

For ease of maintenance out of doors no steel structure made from rolled sections can compete with one of welded tubular construction. Although some of the joints are awkward to prepare if full development of strength is demanded, the provision of flat landing areas at the joints overcomes this difficulty without sacrificing symmetry and strength. The resultant marked simplication of the joints leads automatically to welds of good quality. A successful scheme is illustrated in Figs. 16–18, which show how local flats are produced very quickly by forging in a simple jig and also the neatness of the complex intersection points.

Every engineer could readily cite examples of designs in his own sphere of action illustrative of fitness for purpose and ease of production. I hope that from my own sphere I have provided some food for thought and have illustrated that right quality does not come automatically, but must be inherent in each design, must be worked for in every step of the producing process, and must finally be vigilantly checked at each stage of manufacture.

Welding in the Production of Marine Oil Engines

By J. A. Dorrat, A.H.W.C., M.I.E.E., M.INST.W.

The introduction of machine welding for the production of marine oil engines has meant that many factors acceptable for manual welding have had to be reviewed and changed to meet the new requirements.

The paper describes how the materials, design, edge preparation, and assembly affect the planning of engine manufacture, and indicates, on the basis of practical experience, how each of these factors should be considered in relation to the service requirements of the finished construction. Such features as distortion, manipulation, and inspection are considered in some detail.

THE attitude towards welding has so changed in recent years that planned production is now possible. Welding was such a useful tool and so easy to adopt, that little consideration was given in the early days to the accuracy of joint set up. The job was often assembled roughly, and weld metal was used to fill the gaps. Even so, much was accomplished and the jobs have served their purpose. It was, however, realized that the cost of weld metal, expressed as a price per pound deposited, was much more expensive than plate, and that control over the accuracy of joint fit would reduce the welding times and overall cost of fabrication.

More recently, the control of quality became important when welding was to be used under more severe loading conditions. This control cannot be entirely left to inspection because of the limitations of our testing methods, and the need for procedure control at all stages of manufacture became apparent as the accuracy of joint preparation and welding techniques increased.

This general trend, whilst naturally improving manual welding, is the vital factor which makes machine welding possible. But it must be remembered that improvements in design can be fully realized only when the factors appertaining to manufacture reach the same degree of development.

Much has been said in the past about the need for quantity production before machine welding can be economical; yet this is not necessarily true. The real requirement is the reduction of handling time or the maintenance of a duty cycle at a level that gives machine welding an overall advantage in time. Then any advantage in quality and consistency can be accepted as an extra.

Paper presented to the North Eastern (Tyneside) Branch of the Institute on 3rd December, 1959. Mr. Dorrat is Welding Engineer to the Richardsons, Westgarth Group of Companies.

These thoughts have led to the introduction of machine welding into the Jobbing Shop, and the paper will deal with this development.

Materials

The efficient use of welding clearly requires an appreciation of all the factors involved, and the first factor to be considered is the suitability of the design. It must satisfy the functional requirements and accommodate the welding process generally in two respects; the compatibility of the materials, and detail to suit the application of welding.

Taking the simplest case first, namely the general fabrications required for diesel bedplates and the like, the main requirement is rigidity, so that in general the stresses will be low, particularly when there is no real need to economize in weight.

The choice of mechanical properties will depend more on Young's Modulus than on the ultimate tensile strength, and as the modulus is the same for all mild steels, the exact specification of tensile strength is of secondary importance.

Only readily weldable steels should be used. A definition of weldability is not too easy, for it depends not only on the analysis but on the mass of metal in the joint, the joint design, and the welding process. It must, however, take into account the degree of local hardening, and more particularly the easy way with which crack-free welds and base metal can be assured.

With selected joint designs, mild steels in the 26–32 tons/sq.in. range, having carbon not exceeding 0·25%, and sulphur and phosphorus each not exceeding 0·06% are generally satisfactory.

Modern techniques, using large electrodes with high currents, give adequate base-metal heating for sufficient time to prevent undue hardening of steels in this carbon range. The impurities too are well within the safe limits. Phosphorus has never really been

troublesome. The effect of sulphur on hot cracking is adequately checked by the manganese available from the electrode coating and the base metal, and the effect of a reduction from 0·06% to 0·05% will be unnoticed.

It is usual nowadays to employ low-hydrogen electrodes for arc welding under conditions of severe restraint, which include the heavier sections. Furthermore, it is normally considered good practice to preheat heavy sections, and guidance on this is given in some of the welding codes.

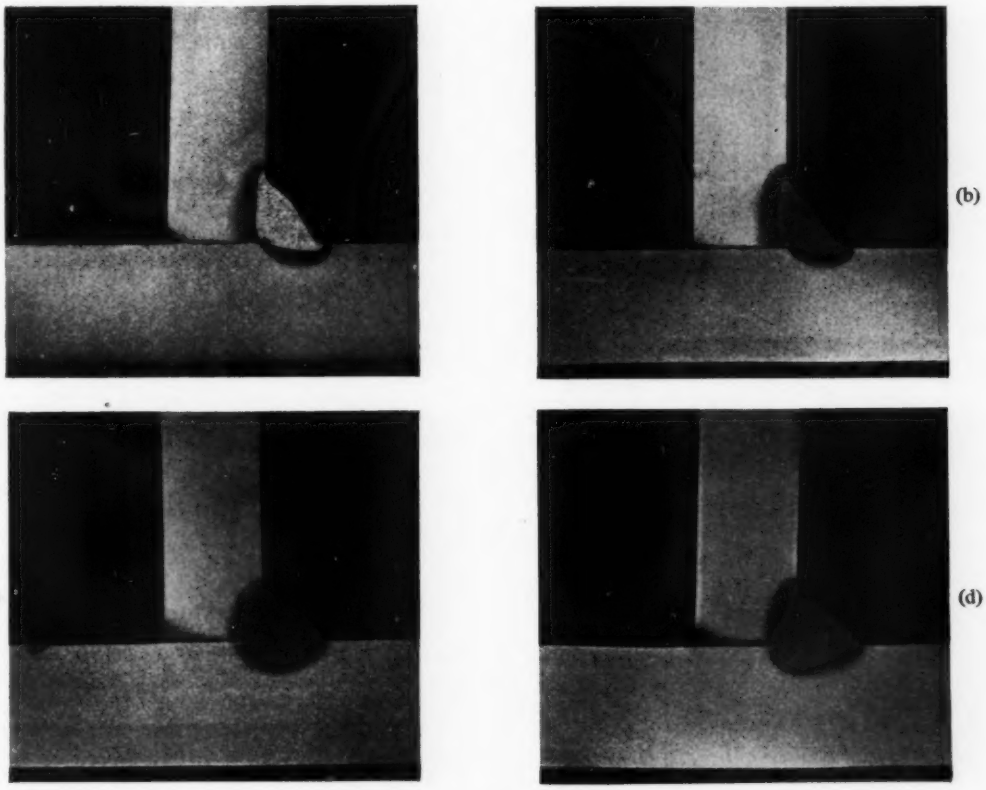
Design

The designer must treat his welding shop as he would a machine shop. For years it has been the practice to design components within the capacity of the machine tools available in the machine shops, and to bear in mind, when proportioning the casting or fabrication, the facings and joints that require machining.

So it should be with welding. If the welding shop has welding machines for circular and longitudinal welding operations, consideration should be given in the design stage as to how these operations can be carried out with the minimum of handling and the easiest setting up. This will involve the disposition of welds, the choice of preparations, size and form of welds (fillet or butt), sub-assemblies and distortion considerations during welding.

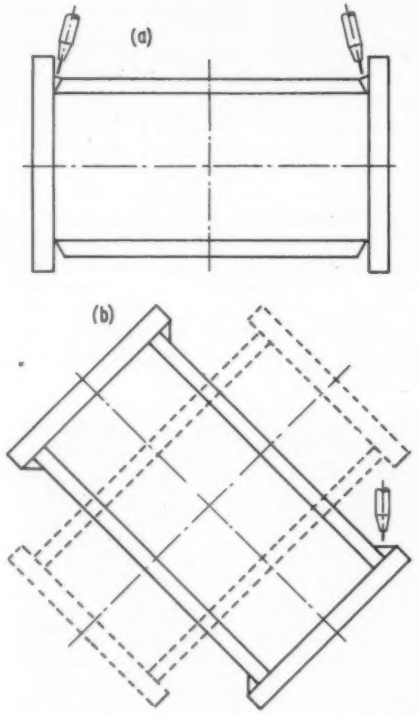
Considering fillet welds, which feature most prominently in marine fabrications, standing fillets must generally be limited in size to $\frac{5}{16}$ in. leg length for single runs, even with machine welding (Fig. 1), so that, other things being equal, every effort should be exercised to use no more than this, for machine-made multi-run fillets are not favoured in this position. It therefore follows that for larger sizes arrangements for manipulating the work piece must be available.

The next variant is the use of a preparation on one plate edge with a limitation of the vertical fillet leg. This introduces, in most cases, a further cutting operation to prepare the chamfer, but eliminates manipulation into the flat or vee position, except for the heavier welds (Fig. 2).

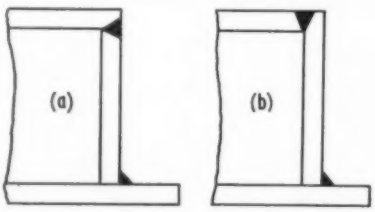


1—*Macrographs of* $\frac{1}{16}$ *in. fillet welds:* (a) *and* (b) *Manual;* (c) *and* (d) *machine*

For all types of fillet weld attaching webs to flanges the location of the welds requires consideration, and if one has to be done in the overhead position, or is generally less accessible, some thought should be given to the limitation of size, so that it can be deposited rapidly by manual welding and the outside main weld completed by machine. Where the loads are light, and in particular for box structures, which are so rigid that bending against the root of the fillet will not occur, intermittent welding may be used if it is not considered safe to omit welding entirely.



2—*Welding positions for* (a) *butt welding;* (b) *fillet welding*



3—*Alternative end-flange joints*

The use of a smaller inside manual weld may be desirable during assembly to ensure sufficient stiffness of the work piece for handling, or to avoid distortion during final welding. Corner welds can be similarly treated.

The more usual arrangement for joints made to end-flanges of bedplates gives a weld in the horizontal plane (Fig. 3*a*) which can be readily changed (Fig. 3*b*) to ensure downhand welding with the orthodox welding machine.

The arrangement of butt welds should also be given the same consideration. The choice is wider, but factors such as accessibility and the availability of internal welding heads must be considered.

Where external welding only is possible, because of plant or design limitations, some form of asymmetrical V or J preparation will be suitable. As in the case of fillet welds, the inside weld can be made first so that it will not only hold the pieces together but act as a backing for the machine runs.

As is generally known, the control of initial root penetration through a butt by machine welding is not possible without some form of backing, which may be either flux or metal. The thickness of metal varies with the joint thickness, but a root $\frac{3}{8}$ in. thick is of the correct order when welding can be done by machine from both sides.

For this reason, sub-assembly of parts may be desirable, but an assembly technique for manual welding, in which the job is generally assembled before welding commences, will not necessarily be ideal for machine welding.

Weld sizes

Excessive welding, like over-designing, must be avoided, and by the correct proportioning of welding much unnecessary distortion can be avoided. This is an extremely important facet of welding and, whilst there are some procedures which reduce distortion, it must always be borne in mind that its entire elimination is almost impossible; the aim should be to keep it within acceptable limits.

It is in the design stage that most can be done to reduce this trouble. Towards this end, and particularly in new designs, weld sizes should be calculated. In box-type structures, carrying static loads, the calculated weld sizes may often be very small so that metallurgical considerations become important. For example, sound crack-free arc welds cannot be deposited in the smallest sizes under restrained conditions; but guidance is available as to the recommended minimum practical fillet sizes for mild and alloy steels, based on considerable experience in the structural field. Tables of sizes for both mild and alloy steels are published in British Standards specifications for all kinds of structural steel work. In this field there are generally accepted empirical rules for safe working loads and design techniques, which simplify the application of such data, but in marine work the individual designer has to decide the stress levels and the extent of the dynamic loading. He is, therefore, tempted to play safe and so involve the shops in more welding, additional plate edge preparation, and all the troubles of excessive distortion and higher costs.

The factors that govern the properties of fillet welds have been studied over many years, and the various types can be classified into categories sufficiently precise for engine parts designed with the normal factors of safety.

Fatigue

From the designer's standpoint weld metal is just ordinary mild steel, having much the same properties as the parent metal which it joins. Therefore, calculating its load-carrying capacity is merely the application of ordinary mechanical design. The behaviour of the weld metal in the engine structure also follows the accepted rules, and thus an abrupt change in section will cause a stress concentration which can, under fatigue conditions, raise the stress level above the safe value. It is here that the greatest difficulty arises; namely, the determination of which part of the engine will have to carry fatigue loads at a high level. There are, of course, some obvious examples, such as fuel pipes, which are subject to high intensity pulsations,

and designs can be worked out to suit the conditions. On the other hand bedplates, in which the stress level is generally low, may have some sections in which fatigue stresses reach dangerous levels. Depending on the design, some columns may carry no direct stresses, whilst others may take the firing loads of the engine and the welds can be subjected to heavy stresses.

The British Welding Research Association have given useful information on the relative merits of various joints and little harm can be done by repeating the data (Fig. 4). The differences between the types of weld are quite marked. Other factors have been shown to affect fatigue strength, but these are small compared with the effect of weld shape.

Generally, little can be gained by using higher strength weld metal, for to be effective its surface finish, heat-treatment, and general soundness require special attention. On the other hand, in ordinary structures, slight porosity and internal imperfections matter little compared with the surface finish of the weld. Similarly, there is no evidence to show that stress relief improves the fatigue strength of mild steel.

Corrosion fatigue

This trouble is not unfamiliar in marine work, as it sometimes affects running gear, but it does not seem to have occurred in any cases of fabrication.

This is fortunate, for unlike stress fatigue, there is no limiting fatigue stress below which the structure is safe. When corrosion sets in, local stress concentrations are produced and ultimate failure is only a question of time.

Distortion

Quite apart from the avoidance of overwelding, which must contribute to distortion, the disposition and detail design of the welds also has to be considered.

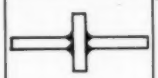
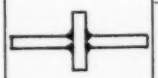
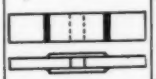
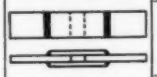
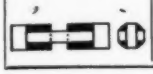
In general, text books state that the fewer runs required to make a weld the lower will be the angular distortion in both fillet and butt welds. In butt welds, a wide single-V will be worse than U and J preparations. Again, if the weld contraction can be taken up in the plane of the plates, there will be less angular distortion, and as direct contraction is generally less troublesome, allowance can be made if the maintenance of overall dimensions is important. The condition can be more easily met with deep-penetration electrodes and even better with machine welding. Where a large amount of the weld is made in one run and the weld proportions give a depth probably greater than the width, minimum distortion conditions exist. For multi-run butt welds, the careful proportioning of the size of the weld preparation on each side of the plate, coupled with controlled welding conditions (whether manual or automatic or a mixture of both) can give distortion-free welds. These considerations are generally preferred to the older methods of trial and error on a job that has been specifically designed for welding; hence the use of back step techniques and similar methods is becoming outmoded.

Some of the edge preparations for butt welds have been in use for years, and the best example applied to manual welding is the asymmetrical V preparation in which the smaller side is welded first and the greater amount of weld metal on the second side brings the plates back level. This can also be done with machine welding and, because of the easier control over the welding conditions, the results can be expected to be more consistent. In machine welding, it is often convenient to weld as much as possible from one side and it is surprising how far this can be done without trouble, provided that the configuration of the joint is suitable. In cylindrical work there would appear to be no limit, if the ratio of thickness to diameter is such that sinking at the weld does not occur, and the curvature of the plate is sufficient to keep the plates level. In machine welding the distortion level will generally be lower than with manual welding and will vary with the size and type of preparation as well as whether single heavy or multi-run techniques are employed.

Consideration should next be given to T joints made with fillet or butt welds. For lightly loaded parts, where the minimum size fillet weld is required, little distortion should be experienced. However, conditions can be troublesome when the butting plate edge is prepared, particularly when all welding is from one side. With this situation there is little that can be done to reduce the distortion, for the flange plate, which may be comparatively thin, will bend at the weld. It is

4—*Fatigue strength of welded joints in mild steel* (Courtesy *British Welding Research Association*)

Max. stress range (tons/sq.in.) for 2×10^8 *cycles*

Type of Joint	*Description*	*Alternating push pull*	*Repeating Tension*
	V-butt, root sealed, machined flush	±9·0	0 to 14
	V-butt, root sealed, as welded	±7·0	0 to 5·5
	V-butt, root unsealed, as welded	±6·0	0 to 3·5
	Cross joint, plates fully bevelled, complete fusion at root	±5·0	0 to 4·0
	Cross joint, plates partially bevelled, incomplete fusion at root	±3·7	0 to 7·0
	Cross joint, no preparation, plain fillets	±2·25	0 to 4·0
	Lap joint, concave end fillets	±3·4	0 to 6·5
	Lap joint, plain end fillets	±2·8	0 to 5·2
	Lap joint, concave side fillets	±3·7	0 to 7·0
	Lap joint, plain side fillets	±2·6	0 to 5·0

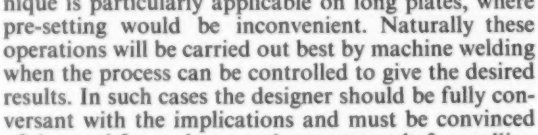
5—Doxford engine column assembly

difficult and seldom successful to restrain this mechanically.

The obvious way to avoid this difficulty is to pre-set the plate to take account of the angular distortion from welding. This may create difficulties in setting up, and the degree of pre-set and its exact position must be accurately pre-determined. In addition, the amount of pre-setting that is possible can well differ from that created by welding and so give imperfect correction.

Another method, which is generally limited to plates whose surfaces will be subsequently machined, is to run a bead of weld metal along the line where distortion has taken place, so that the additional weld will contract and counteract the plate distortion. This technique is particularly applicable on long plates, where pre-setting would be inconvenient. Naturally these operations will be carried out best by machine welding when the process can be controlled to give the desired results. In such cases the designer should be fully conversant with the implications and must be convinced of the need for such corrective measures before calling for such a technique.

Neither of these methods is altogether desirable, for each introduces another operation and adds to the expense. That is not to say that the overall cost is greater, for it may well be cheaper to incur the cost of an additional planned operation than to have to correct the distortion afterwards.



6—Sulzer engine bed assembly

Material Preparation

The usual types of plate working machinery are still generally used, and progress in their further development is of necessity slow.

Flame-cutting machines are unsurpassed for the cutting of shapes and thick sections. Whilst portable lightweight machines are popular, most cutting is still done on fixed machines. Template machines for repetitive work are not being replaced at all rapidly by optical tracing machines whose applications are economic only in limited fields. Whilst coal gas is often used for square cutting, one of the higher flame temperature gases is preferred for chamfering.

Assembly

In all marine fabrication, the provision of level cast iron floor plates over the assembly area is essential. Such a bed can be used for the layout and setting up of single jobs and equally well forms the base for the building up of assembly fixtures.

The method used for a particular engine will depend on the design. In one particular engine the accurate shaping of the plates makes fixtures unnecessary. The plates themselves are assembled, as shown in Fig. 5, on spacing blocks set on the beds, and others are used to separate the web plates by the desired amount. The web plates are squared up readily from the bed so that the boundary or flange plates can be assembled to them and held in position with flame-cut tee-headed clamps and held rigid with wedges driven in under the head. The flanges are tack welded in position, and any inside welding required is done before too many plates are put together to interfere with access to the inside. When this is done, the remainder of the stiffeners and details can be added. Designs of this type do not lend themselves to sub-assembly but when machine welding is used there may be some advantage in omitting certain details until the end.

Similarly, the entablature for the same engine is of

a comparable design and does not lend itself to sub-assembly. The accurately flame-cut plates are self-jigging and can be assembled on the floor and progressively built up and tack welded.

The bedplate can have the transverse girders built up separately and, as has been shown, this operation can be mechanized. Despite this, the design is not fundamentally suited to sub-assembly pre-fabrication.

On the other hand, the design shown in Fig. 6 is fabricated from sub-assemblies, all of which can be welded more or less completely before being finally brought together. This design also lends itself to jig assembly. The jigs can be very simple, consisting of a number of brackets bolted to the floor plates. The same arrangement applies to both the sub-assemblies and the main units.

The columns for this engine can similarly be made in a series of sub-assemblies which, after welding, come together to form the complete unit. This leaves only a small amount of welding to be done on the relatively heavy, almost completed fabrication, with the minimum requirements for final welding and handling.

Automatic Welding Machines

For machine welding it is now customary to accept only equipment that is capable of using and feeding a continuous wire from a coil and can feed the current into the core wire near the point of welding, so that high welding currents can be used without overheating the wire. By this means high rates of deposition can be obtained with consistency of deposit. In general, the control gear for wire feed is dissociated from the head, which thus becomes little more than a drive unit that may be slung on a suitable supporting arm for ready positioning over the weld seams. This feature is really the key to economical machine welding and, although satisfactory heads have been available for years, engineers have not given enough thought to their economic application.

From the welding aspect it is unimportant whether the head is moved or is in a fixed position over a moving seam, but this is extremely important from the economical viewpoint.

As previously mentioned, the method to be used will depend on the size and design of the component as well as the shop layout and particularly the lifting facilities available. If the crane capacity is already taxed, help afforded by welding manipulation might be extremely important in reducing "waiting time" whereas if there are surplus crane lifting facilities, savings in capital cost can be made by the use of less complicated manipulation for welding.

Open-arc process

Almost all electrodes made for automatic open-arc welding have a core wire with an overlay of smaller wires which project above the surface of the coating and enable electrical contact to be made to the core. The core wire is limited to about 4 s.w.g. owing to the difficulty of providing enough flux without impairing the strength of the electrode and without the possibility of undue damage during coiling and uncoiling. The coatings can be either rutile or basic types, giving weld deposits with the characteristics of these coatings.

So far, gas shielding alone has not proved to be satisfactory except with a comparatively small welding wire of very special type, resulting in a high cost for process materials which puts the process at a disadvantage in comparison with the normal type of electrode wire used on heavy work. But a recent successful development has been the use of separate CO_2 shielding with a rutile type electrode.

Submerged-arc process

This process, using a bare electrode which is melted under a blanket of granular flux, can be used for such a range of materials and thicknesses that it is almost impossible to define its relationship with the open-arc. The flux may or may not be pre-fused. Not only can this method be readily applied to mild steels but, with suitable compounded fluxes, alloy welds can be made using low-carbon steel electrode wire. But this technique of welding of alloy steels is limited, and an alloy core wire with a standard granular flux is preferred.

An engine designed to suit sub-assembly production can be easily machine welded. One manufacturer has used portable automatic submerged-arc machines virtually without fixtures by laying the machine rails on the job and running the head over the seam. High quality welds were efficiently made by this method for some time but greater efficiency has since been achieved by taking the job to the machine. This is a tidier method, for there are no trailing welding cables, and lining up of the rails for each seam is not necessary.

Both the moving-bogie and moving-head machines have been used extensively, and it is difficult to decide which is preferred for this type of work. The lifting operations are the same for each, and as the welding current and wire size are the same the welding speeds are identical. If the production run is long enough some improvements could be expected by providing arrangements for turning the assemblies over between welds.

Both open-arc and submerged-arc processes have been used on the type of work described and so far no preference has been shown for either.

Manipulators

Whilst many applications have been found for the rotating and tilting manipulator, its greatest use must be for the smaller jobs, mainly because of the time taken for setting up and attaching heavy jobs to the face plate. Also because of the general construction of the manipulator the table must be fairly high, particularly when it tilts to 45° beyond the vertical, and this will require a good deal of climbing on the part of the welder and other operatives. When the equipment is used for large jobs, like diesel columns, a compromise can be made by sinking the manipulator in a pit. An example of this is shown in Fig. 7. With such an arrangement a space of about 16 ft is required to swing the column. Apart from the main welds joining the flanges to the webs, the other welds are comparatively short, and to obtain maximum efficiency the setting time for the head must be small, so the vertical and horizontal movements should be motor driven and under push-button control.

The size of the columns generally limits the tilting

of the face plate to between the vertical and 45° positions, and when the application is limited to special cases the angle can even be pre-set. This simplifies the equipment and greatly reduces the cost, although it may introduce loading difficulties, but these can often be readily overcome by attaching fittings to the table. For the columns in question the tube stiffeners can be used for location purposes. Otherwise a slight design

7—Positioning of diesel engine columns

modification to include a permanent locator will serve the same purpose. Some simple method of location is essential so that setting-up time is reduced to a minimum, particularly in this type of job where the work must be turned over before the second side can be welded.

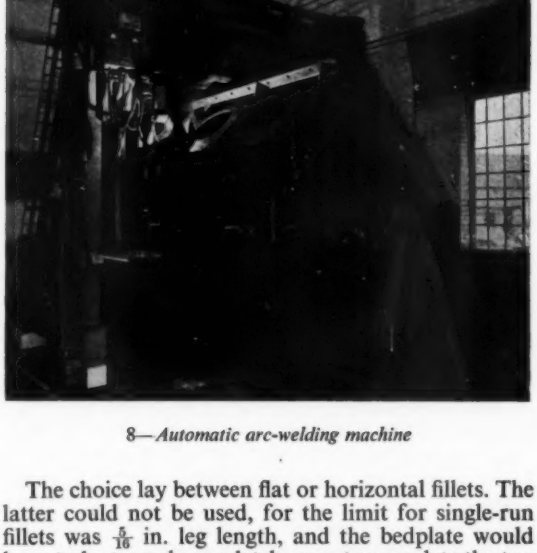
The bedplate of the same engine has proved to be an interesting exercise. Some sub-assembly has been designed into it, comprising the bearing housings and other details which are welded on to the transverse girders. These girders have single webs with the housings machined and fitted and attached by fillet welds. Some trouble convinced the author that these should be changed to butt welds, and this change also facilitated the introduction of machine welding.

Bearing in mind that the success of machine welding depends on the efficiency of the handling, it was obvious that these could be best assembled in pairs. Thus continuous welding could be accomplished by arranging for the plates to be rotated under a fixed welding head. It was also obvious that if a burning head were to be incorporated on the same set-up it would save further handling. As a result of method study the plates were jigged on the rotating table, and the hole was flame cut with the weld preparation ready at one setting to take the pre-machined bearing housings. This was followed by the top-side weld, and by turning the complete jig over the second side weld could be made.

In machine welding the use of run-on and run-off plates ensures good welding right to the end of the seams without the usual manual welding and chipping. With work of this type these plates should allow continuity of circular welding on the two separate girder plates, which can then be flame cut apart, leaving perfect edges at the ends of the welds.

In such jobs, the choice of weld preparation enables distortion to be controlled and provides a reliable degree of penetration. But practical trials are always required to prove and even modify weld details. The trials must be adequately recorded, and procedure control of this type is becoming accepted practice.

This bedplate was originally, and for many years, only manually welded, so that the problem of machine welding proved to be difficult, particularly when any such change should show some advantage. The major difficulty lay in the number of positions in which the welds had to be made, and even with manual welding many heavy crane lifts were required. After consideration it seemed that most savings could be effected if the amount of handling could be reduced. Thus, if sufficient length of welding could be done in two main directions less turns would be needed. By far the largest amount of welding was in the longitudinal direction, so the joints in this plane were considered first.



8—Automatic arc-welding machine

The choice lay between flat or horizontal fillets. The latter could not be used, for the limit for single-run fillets was $\frac{5}{16}$ in. leg length, and the bedplate would have to be turned completely over to complete the top and bottom welds. It therefore appeared to be a better proposition to manipulate the bedplate on a longitudinal axis and to do all the outside welds in the flat position. The welds could then be made to any size required, even to the limitations of the size of those inside and so reduce the proportion of manual welding time.

The method of rotating such a structure had to be considered and, after studying the use of hoops to roll the bed in, it was decided that temporary trunnions bolted to the transverse girders would be the most satisfactory technique. With these fitted the bedplate

can be dropped into trunnion bearings, one of which carries a drive unit which can engage the trunnion and so rotate the bedplate to the required welding position. With the stands set on steelwork pre-set in the floor the alignment of the welds is assured (Fig. 8).

The choice of the welding process calls for some care. In this instance, the bedplate and columns, where fairly small fillet welds predominate, are suitable subjects for one of the open-arc processes, for the positioning of the arc at the end of the seam and any subsequent slight adjustment during the 20–30 ft. run is easy. Also, in the case of fillet welds, the use of run-off plates is not always possible, so that open-arc welding is more satisfactory.

Some speed may have to be sacrificed on butt joints because of the undesirability of changing wire sizes after welding has started, but this loss of speed can often be small in relation to the overall advantage. After the plant has been installed it is a simple matter to change from open-arc to submerged-arc welding, by replacing the nozzle. This enables the open-arc process to be used for welding pipes, cylinders, and drums where the joints are butt welds, and the submerged-arc process for the butt welds on the bearing housings and transverse girders.

Inspection Methods

Control of quality

With machine welding in particular the process can be controlled easily to give maximum efficiency. It is simple to investigate joint designs and welding techniques and to find the optimum operating conditions. The effect of variations in current and speed can be investigated by macro-examination of weld sections to determine the permissible latitude, and then the working limits can be set.

The control of these factors and the process materials will result in consistency of mechanical properties. For general fabrications this is sufficient, but where additional proof is required three non-destructive methods of test are available in the form of X- or gamma-rays, and ultrasonic and magnetic particle inspection. In the marine shop magnetic methods are probably the most used of the three, although they are virtually limited to the detection of surface cracks in ferrous materials. The training of operators is comparatively easy. Figure 9 shows a typical application where the welds round the bearing housing attachment are all examined for surface cracks. Cracks in such an area where fatigue stresses exist are dangerous, for they can quickly develop to an alarming extent.

The principle involved in the method is that of magnetizing the area under test and floating finely divided magnetic materials over the surface being inspected. Any discontinuity of the surface will cause magnetic 'fringing' with an accumulation of the magnetic particles which show up the edge of the crack. The magnetic field, which should be quite strong, may be obtained from permanent magnets or by the flow of current. For best resolution the field should be normal to the suspected crack. This can usually be arranged

9—Magnetic particle inspection of bearing housing

with some degree of certainty with a knowledge of the geometry of the welds and the likely direction of possible cracks.

The use of either a.c. or d.c. with conductors wound round the area is good, but the application is not always easy. The main use is for comparatively small circular work.

Passing current through the structure is usually undesirable owing to the imperfect contact made to the job by hand-held probes. This can lead to arcing, which produces local hard zones with radiating cracks.

For the detection of under-surface defects ultrasonic methods have many applications. The principle used is the propagation of an ultrasonic beam into the steel plate or forging and the reception of the reflected waves from the other side of the plate or from any discontinuities in the weld. The reflections are displayed on a cathode ray tube and the indications are a measure of the defects, provided that a suitable frequency and scanning technique are chosen. There are standard methods of calibration, so that on regular constructions quick and accurate examinations can be made.

The technique can also be applied to the determination of plate thickness from one side only, and for the location of laminations and the mapping of their extent.

Gamma- and X-rays are little used for the inspection of diesel machinery, for the limited number of butt welds and their inaccessibility makes the application generally impossible. But ancillary gear, such as air receivers with butt welded seams, are among those items that can be X-rayed, whilst pipe joints can be examined with gamma-rays.

Acknowledgments

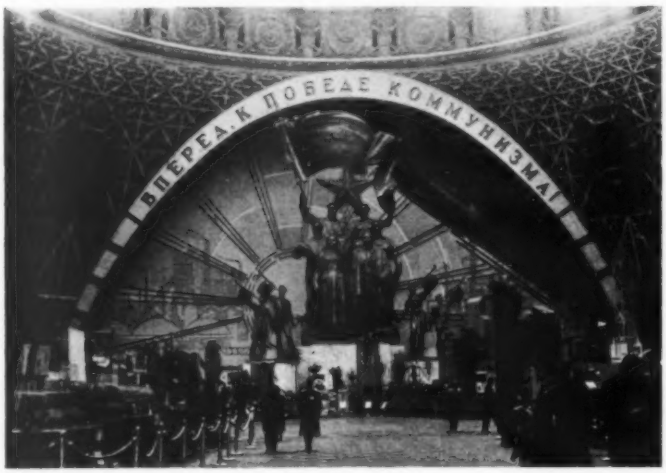
The author wishes to thank Mr. J. R. Mackay, Managing Director of Richardsons, Westgarth & Co. Ltd., for permission to present this paper.

Welding Mission to the U.S.S.R.

Cover illustration—*One of the Main Avenues of the Moscow Exhibition Hall*

A brief report on the visit of British welding technologists to the Soviet Union in September 1960 was published in the December 1960 issue of B.W.J.*

The technical report of the mission is now presented. Readers requiring further, more detailed information, should write to the Secretary of the Institute of Welding, who will pass the enquiry to the appropriate member of the British team.



Ornamental end of building shown on cover. Machines in the background are not welding exhibits

THE Mission was organized by the Institute of Welding with the U.S.S.R. State Scientific and Technical Committee, Moscow, through the British Embassy, and its purpose was to see the research and application of welding and welding processes in the U.S.S.R.

The Party consisted of: Mr. E. Seymour-Semper (Hancock & Co. (Engineers) Ltd.) (Leader); Mr. E. V. Beatson (Group Research Centre, Joseph Lucas Ltd.); Mr. E. F. Burford (G. A. Harvey & Co. (London) Ltd.); Mr. J. A. Dorrat (Richardsons, Westgarth & Co. Ltd.); Mr. M. G. Hipkins* (Chief Metallurgist, Head Wrightson & Co. Ltd.); Mr. W. C. Holliday (Chief Welding Engineer, Whessoe Ltd.); Dr. R. Weck (Director of Research, British Welding Research Association); and three other members of the Association's staff—Dr. A. A. Wells, Mr. H. F. Tremlett, Mr. P. T. Houldcroft.

Meetings were held at the offices of the State Scientific & Technical Committee, who arranged for the Mission to visit the following:

The Welding Exhibition at the Exhibition of Economic Achievement of the U.S.S.R., Moscow; The Baikov Institute of Metallurgy, Moscow; The Likhachev Automobile Works, Moscow; TsNIITMASh—Equipment Design Institute; Metallicheskii zavod—Turbine Works, Leningrad; VNIIESO—Research Institute, Leningrad; The Paton Institute of Welding, Kiev; Kherson Shipbuilding Co., Kherson.

For some of the visits the party split up, some to a research establishment and some to works.

General

The arrangements were well organized; the Mission was well received at all the Institutes and Works visited and questions were asked from both sides and generally answered with full information. Discussions were frank and friendly and technical literature was provided. Our hosts appeared to be familiar with most information on welding published in Britain and they in turn asked many questions of us. This led to many profitable discussions.

In addition, facilities were provided to see the

* It is regretted that the name of Mr. M. G. Hipkins of Head Wrightson & Co. Ltd. was inadvertently omitted from the earlier report.

equipment and operation of other types of welding, including:

Submerged-arc welding—generally heavy deposit welds with thin wire electrodes and also in the vertical welding position.

The adaptation of this process to surface deposit or cladding purposes using strip electrodes.

The wide use of gas-shielded arc welding, using CO_2 and argon gases—in all welding positions—using uncoated thin-gauge wire.

Resistance welding for normal and exceptional requirements, such as the field welding of large diameter pipes.

A new process—friction welding for bars and tubes, etc.

Equipment for electron spot or beam welding in a vacuum chamber for such material as titanium, tantalum, nickel, etc.

Other sources of interest were:

The pre-fabrication and erection of large vertical-type storage tanks, such as oil tanks, welded in the shops as flat sheets for the sides and bottom, and rolled around formers. On site they were unrolled and welded together.

The construction of flat coiled pipes, essentially in welded strip form, which can be unwound and converted to cylindrical form by pressurizing.

A unique method of ship hull fabrication and launching.

Quality control, the liaison between research, development and production and the training of welding personnel and supervision.

The outstanding impressions of the tour were:

The extensive welding research and development.

The wide and extensive use of automatic and semi-automatic welding in industry.

The use of heavy weld deposits in comparison with layer or multi-run welding in the U.K. and U.S.A., resulting in greatly increased output.

Development of friction welding to the stage of application.

The liaison between research and production resulting in the quick translation of theory to practice and the adaptation of welding methods to production problems.

The use in production of electro-slag welding.

The U.S.S.R. has a 7-Year Plan (1958–1965) which includes welding, and the following are some of the objectives:

The output of 1965 is to be double that in 1959, when it stood at 7,600,000 tons of welded products.

50% of all welding must be mechanized. This figure is now at 80% in shipyards.

For submerged-arc welding 50,000 tons of flux were used in 1959; this is to be 150,000 tons in 1965.

230,000 tons of welding electrodes were used in 1959; this is to be increased to 420,000 tons in 1965.

The manufacture of gases for welding is to be increased six times.

There are 200 electro-slag welding sets now in use in 40 locations; these are to be increased 2½ times by 1965.

Whilst considerable research is being done it seems that this is more applied than fundamental. Many hundreds of research and development workers are engaged in the application of welding processes and techniques of production. Work is also being done in the development of new processes as well as the application for special purposes of existing processes. Great importance is also attached to the need for fully trained technologists and technicians in all production processes involving welding.

It is known that the Soviet Union has a big educational programme and as it appears to be fully realized what an important part welding can play in productivity, considerable emphasis is placed on education in welding technology at all levels. A recent decree ordains that every plant using welding as a production process must have a qualified welding engineer on its staff. The lack of educational facilities in welding in Britain is a serious challenge to this country, and it would seem that in the Soviet Union there is a greater realization than there is in Britain of the part which welding can play in production.

Arc Welding

During the visit very little manual arc welding was seen. This is a result of the policy adopted during the development of heavy engineering and probably of the need to conserve labour by concentrating on a limited number of processes. This has been done by accepting submerged-arc welding as the automatic method and inert-gas arc welding for the other applications. This has been developed to the stage at which it can be applied to many of the constructions on which we in this country would prefer to use metal-arc welding. It was not possible to assess the economics of the process when compared with particular metal-arc applications but this is probably of secondary importance to them owing to the necessity for developing and adopting a limited number of processes as quickly as possible.

All equipment was of a robust nature and of the simplest possible construction. For example, in the case of shielded metal-arc welding no special arrangements were made for the wire reels other than a base with a vertical spindle on which the reel rotated and this was in all cases independent of the wire feed mechanism. The wire feed mechanism was cut down to the bare essentials and included the feed motor, gear box and feed rolls built into an extremely compact unit.

The development of automatic welding was concentrated on a limited number of types of head and in all cases where arc voltage control was provided this was of the magnetic amplifier type.

In general, the welding current used with all this type of equipment was limited to 1,000 amp, whilst the majority seemed to work in the region of 600 amp using 2½ to 3½ mm wires.

The heads were compact and of sound construction and in the case of the larger heads great care was taken to provide adequate wire straightening facilities such as roller before the feed rolls and again between the feed rolls and the nozzle. In all discussions the Soviet engineers emphasized the importance of wire control for efficient welding.

Many simple adaptations of these heads were seen for both circle and straight welding using simple and comparatively cheap 'set-ups' for both fillet and butt welding.

Vertical welding

The principle of employing suitably shaped and designed copper backing bars has been developed for vertical welding of plates up to 20 mm thick. In this case, the welding head is made to climb vertically on a suitable track which can be positioned against the vertical welding seam. With comparatively small electrode wire and current of about 600 amp, the machine

is made to feed the wire into the joint and fuse through the complete thickness of the plate. The backing bars, which move up with the welding head, retain the weld metal between the joint until it has solidified. The welding flux is of the granular type used in the submerged-arc process and is fed in a similar manner.

The process in many ways resembles the electroslag process except that unmelted granular flux covers the weld.

Because the electrode wire must be fed in at an angle to the joint, setting up is rather more difficult than for ordinary submerged-arc welding, but with the conditions set correctly, the process appears to be satisfactory.

Bogie-type machine with travelling backing shoe

This consisted of a standard metal-arc welding head mounted on a 3-wheeled bogie so that the leading wheel was located in the gap between the butted plates. A water-cooled spring-loaded copper backing bar on the underside of the weld seam was supported by a wide thin member which passed through the gap between the plates. In the demonstration, submerged-arc welding was used under more or less standard conditions.

The welding of plates 5 or 6 mm thick with complete penetration from the top side and with a well formed penetration bead on the underside was achieved with very little plate distortion. The plates were assembled and held together by tack welding short strips of bar at intervals across the joint. These were welded from one side only so that they could be readily removed as the bogie approached. With an arrangement such as this, it is obvious that provision must be made immediately underneath the joint for the movement of the backing shoe. The whole arrangement was neat and compact and appeared to be developed to the stage of practical application.

Twin-arc girder welding machine

This machine was designed for the fabrication of 'tees' in any thickness plate with flanges not exceeding 350 mm and webs up to 1 m, and required no tacking together of the two members. These simply had to be passed into the feed rolls of the machine and automatically progressed under the two welding arcs at the correct welding speed to produce two $\frac{5}{16}$ in. fillet welds. The process used was submerged-arc welding with powder flux recirculated by the hopper system which was an integral part of the machine. Welding speeds of 35 m/hr were reported.

Backing arrangements

A good deal of attention had been paid to the holding and backing for single-sided automatic butt welding. The method of clamping varied according to the type of work undertaken. For small work which could be threaded over a backing bar, clamps operated by air pressure in an ordinary fire hose were used along with powder packing. Where access to the underside was not easy magnetic clamps were provided to hold the two plates down on the copper backing bar. Owing to the buckle in the plates this did not appear to be entirely satisfactory, and in addition to this clamp heavy weights were used to hold the plates down. Then, again possibly because of the difficulty of obtaining intimate contact between the plates and the copper backing bars, this was augmented by powder flux which could accommodate some of the plate irregularities. These methods in combination were seen in operation on very large assemblies such as prefabricated sections of ships' shell plating.

Nozzle welding

A number of special applications were seen, and probably the most interesting was an arrangement for welding nozzles or stand pipes into a boiler or header. In this case the actual welding machine nozzle was rotated round the fixed tube by the welding head mechanism, and by the progress of the wire through the nozzle actually imparting the rotating motion to the nozzle. Quite a small welding wire was used with powdered flux in the submerged-arc process to produce neat and consistently good welds.

Surfacing

When large surfaces have to be covered with either corrosion-resisting or hard-surfacing material, a new development has been applied in a manner which would appear to be very satisfactory.

One application seen was the coating of the outside surface of a water turbine runner with 18/8 stainless steel to produce a corrosion-resistant surface. The runner casting was a low-grade mild steel casting, and a single layer of deposited metal provided an adequate corrosion-resistant layer. A single layer provided adequate material for subsequent machining.

The standard magnetic amplifier-controlled type automatic welding head is modified to feed a ribbon electrode in place of the ordinary round wire. The type of deposit obtained depends on the quality of the ribbon used and is automatically made under a blanket of powdered pumice and operated in the same manner as a standard automatic welding head. Welding details are as follows:

Ribbon size 15 to 100 mm wide
0·4 to 1·0 mm thick
Welding current up to 12,000 amp
Welding speed 7 in./min (approx.)

For hard surfacing, ribbon made by the continuous casting process is used. Hard deposits made with this ribbon electrode are not entirely free from cracks but despite this, the electrode has been used extensively for many hard surfacing and re-claiming operations. This work seems often to be done under circumstances that would hardly appear to be profitable in this country.

Non-ferrous welding

Considerable development appears to have been made on submerged-arc welding of non-ferrous metals, and examples were displayed of both aluminium and copper welding. One of the applications of aluminium welding was by a tractor-type machine feeding twin wires from a single power source. The convenience of this tractor arrangement was that it could be used both for longitudinal and circumferential seams. In the case of the circumferential seams the tractor was made to rotate inside the bottom of the drum while this was rotated on rolls.

Examples were shown of copper welds made by the submerged-arc process, and these had a good surface appearance.

Inert-Gas Shielded-Arc Process

The gas-shielded arc process is widely used in the U.S.S.R., and by 1965, at the end of the current 7-Year Plan, it is hoped that the consumption of CO_2 as a shielding gas will be six times the 1958 output. This readily shows the rapid increase in the application of the CO_2 process for welding. The equipment was seen working in shipyards, where relatively thin plates were being welded, and also at the TsNIITMASh for the horizontal/vertical welding of plates 100 mm thick. Prior to the introduction of the shielded gas process this welding was done manually using coated electrodes. It was claimed that the properties of the weld metal deposited in this way were superior to the properties of submerged-arc welds; in particular, the impact values. Typical results for U notch specimens tested at 20°C. were:

Submerged-Arc 10–12 kg.m/sq.cm.
CO_2 Process 12–14 kg.m/sq.cm.

These results are not as good as those which had been obtained for welds made with basic coated electrodes, but they were considered to be satisfactory. The equipment could accommodate wire varying from 0·6 to 1·2 mm in diameter. Mechanized equipment had been developed and used for welding mild steel and stainless steel and it was claimed that the mechanical properties of the welds were equal to those of the parent plate. Semi-automatic machines were used for welding in all positions using d.c. from a power source having a flat characteristic curve. The equipment had been developed for mass production work, and a fully automatic installation was seen for attaching flanges up to 200 mm in diameter to tubes, where the flanges revolved below a stationary head.

The largest concentration of semi-automatic machines was seen at the shipyard at Kherson, where the equipment was being used on a scale simulating the manner in which coated electrodes would be used in this country. In fact, in this shipyard, we were told that fully and semi-machine welding processes were used for 85% of the welding. This was readily appreciated since manual welders were not seen at work during the visit, although there were examples of repairs made to seams by manual welding.

The purity of CO_2 used for welding was stated to be 99·5%. CO_2 welding is used on austenitic steels but only when the products are to be used at room temperatures. It was also learned that research work is being done on the use of steam as a shielding gas.

Electro-Slag Welding

A brief description of the electro-slag process is that it is a development of submerged-arc welding with the difference that the heat is put into the slag forming an entrapped and controlled molten pool which in turn fuses the electrode wire(s). It is suited to the welding of thick plates, generally 2 in. and over, and it is claimed that steel blocks 2 m (6 ft 6 in.) thick have been welded by this process, which is a one-operation method through the full thickness of the material.

At the Paton Institute in Kiev we were informed that at present 40 plants were using electro-slag welding in production, 200 machines of all types being employed. It is proposed to increase this by 2½ times by 1965.

Methods of improving the impact properties of electro-slag welds without heat-treatment are being studied, and in this connection it is interesting to report a conversation with Professor Rykalin at the Baikov Institute, who stated that they had successfully refined the structure of electro-slag welds by the application of ultrasonics, but *no* improvement in mechanical properties had resulted.

Several conventional electro-slag machines were seen at the Paton Institute and at TsNIIMASh, where the emphasis was mainly on the use of plate electrodes. At the latter Institute welds have been made at 40° to the vertical, but in production it was stated that 25° was a maximum.

At the Metallicheskii zavod in Leningrad, electro-slag welding of 3 in. thick mild steel rings was being carried out, using a prefabricated electrode assembly. This consisted of three plates approximately ¼ in. thick × 3 in. wide, separated from each other by ¼ in. diameter flexible tubes made by spirally winding wire; down each tube was fed an electrode wire. The whole electrode assembly was consumed, and supplied some 15% of the required filler metal, the remaining 85% being supplied by the wire fed continuously through the tubes during welding. Up to ten rings were stacked on top of each other with spacing pieces ½ in. thick separating them, and were welded as a single job. After completion of the welding the rings were separated by gas cutting through the spacing pieces. Water-cooled copper blocks were clamped on either side of the joint to contain the molten metal and slag. At this plant also were seen large turbine runners which were reported to have been fabricated by conventional electro-slag welding. Heat-treatment after welding was at 750°C., although exceptionally a full normalizing treatment at 920°C. was applied. The latter treatment was always used in boiler construction and was followed by a tempering treatment giving impact properties of 5–6 kg.m/sq.cm (Mesnager).

At the Welding Exhibition there were many examples of electro-slag welding, including a large crankshaft and a gas-holder (100 lb/sq.in.). The latter was not heat-treated after welding. 18/8 stainless steel plates were shown, electro-slag welded using two wires (20–28 V, 400 amp). The electrode wire was stabilized and the need for maintaining a low bath depth (30 mm) was emphasized.

Resistance Welding

At present, resistance welding development appears to be generally comparable with that in the U.K. and the U.S.A. As expected, the emphasis was on general purpose and larger machines, with a percentage of 3-phase welders. Interesting applications included a large transportable butt welder for use in the field on pipes up to approximately 28 in. diameter with an unusual design of transformer, encircling the pipes and supplied from a 300 kW diesel-alternator set, and the

production from two steel strips by twin-head seam welders of continuous coils of subsequently inflatable pipes between 4 and 6 in. diameter. Small machines and special purpose equipments for quantity production of light assemblies did not appear to be so advanced as in the U.K.

Friction Welding

This process, developed in the U.S.S.R., and the subject of several research reports in the past two years, has now reached the stage of advanced machine development and active application to industrial

Selection of friction welded specimens. The machine is in the immediate background

problems. The principles have been described and depend basically on the generation of welding heat by the friction developed between two pieces under pressure, when one is rotated relative to the other. Demonstrations and exhibits indicate that the process has considerable promise in the field of butt welds between bars and tubes and in welding bars and tubes to flat components. It is also applicable to a variety of dissimilar metal combinations including carbon and alloy steels, stainless steel, copper alloy and aluminium. Weld properties may not be quite as good as best quality flash welds in steel, but the possibilities with other metals are attractive. So also is the obvious economy in electrical power requirements. For instance, a machine with a 28 kW motor will weld 3 in. diameter bars in about 10 seconds.

Newer Processes

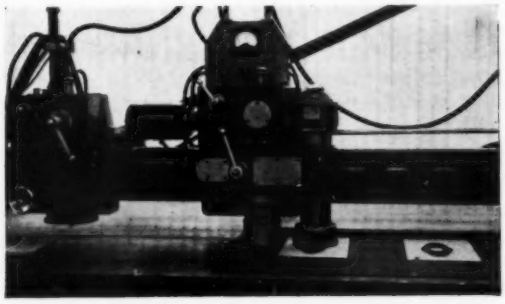
Attention was being given at several of the research centres to research work in new processes, such as ultrasonic welding and electron beam welding. The position appears to be very similar to that in the U.K. An exhibit at the Welding Exhibition in Moscow referred to work at the Institute of Dairy and Meat Industry (not visited) on diffusion welding in vacuum. This work appears to be along similar lines to the very promising work in the U.S.A. and in Britain on the welding of widely dissimilar metals.

An interesting side-light on introducing new processes to production was the widespread use of copper–aluminium cold welds (of conventional design) in the construction of arc welding generators, and the advanced development of machines for making cold butt welds in heavy section aluminium–copper for bus-bars and overhead cables.

Gas Welding and Cutting

Nothing novel was seen in fusion welding by the oxy-acetylene process. At the Welding Exhibition there was a machine for gas pressure welding which was similar to a butt welder in construction, the heat being provided by a large number of blowpipe tips mounted internally in rings. No doubt this process has a field in remote areas where electricity is not available.

Another automatic machine was for the deposition of brass by the Gasflux process. The Gasflux equip-



Tracing head of electronic cutting machine of the edge-following type

ment was similar in construction to that in use in Great Britain and the United States. The design of gas welding equipment generally is similar to ours and there were several oxygen cutting machines at the Exhibition, both portable and stationary. An electronically controlled cutting machine was exhibited, which appeared to be similar to one that has been in use in Britain for the last ten years or so.

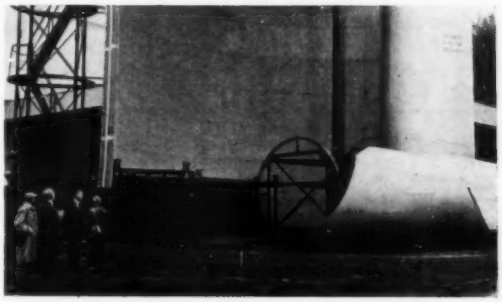
However, the impression gained from the factories visited was that machine cutting is not used to anything like the extent it is in Britain and indeed some of the edge preparation for welding which had been done by manual cutting would have been quite unacceptable here.

Pre-Fabricated Storage Tanks

In the main Exhibition Hall there was a model demonstrating the method adopted for the prefabrication of storage tanks having a capacity up to a maximum of 5,000 cu.m. Outside the Hall was a full-sized tank partially erected.

The method of fabrication at the works is dependent on the size of tank to be constructed. If a tank is limited in capacity to approximately 2,000 cu.m then the shell of the tank is welded with all the plates assembled in the flat position. This is done by positioning the plates and locating them by means of magnetic clamps. The seams are welded on one side and then, by using a conveyor belt, the plate is moved over the end of a roller and passed underneath the points of support for the initial welding so that the other side

can be welded. Thereafter the whole of the welded shell is wound on to a drum of such a diameter as to ensure that the material is strained within the elastic range. This drum is designed so that within its centre is fabricated the access ladder for the storage tank. With the shell welded and wound on to the drum the tank bottom is positioned and welded in a similar manner and wound on to the top of the shell. Meanwhile elsewhere the roof framing, centre post, and roof plates are prepared and loaded on to a wagon. The shell plate and bottom wound on the drum and the roof structure and centre post are transported to site. At the site the drum is lowered on to the prepared foundation, and by the use of a tractor and the drum as a roller the bottom is located. After this the drum is stood in the vertical position and the centre post is



Prefabricated tank, showing method of rolling floor and wall on to formers. A wall-former is shown at the left

erected. Again using a tractor and angle attachment the shell is unrolled, and at the same time it is located in position round the periphery of the tank bottom and tack welded between the bottom and shell; coincident with this operation the rafters between the top of the shell and the centre post are located. It is essential that this is done progressively so as to achieve the correct diameter at the top and bottom of the tank.

Finally, when the whole of the shell is unwound there is one vertical seam left to be welded, in addition to the fillet welding of the shell to bottom and shell to roof. The tank shown at the exhibition was not as well shaped as the tanks we produce in this country, and it appeared that the acceptance standards in the U.S.S.R. may be lower for this class of work.

Tanks 5000 m in diameter are constructed in a similar manner except that a separate drum is used for tank bottom and shell, the bottom being fabricated in two pieces.

We were told that there were at least 8 factories in the U.S.S.R. producing tanks by the technique described.

Quality of Welding

The standard of welding expected by the inspecting committee was discussed at nearly all the works and Institutes visited. Sometimes replies to our questions conflicted but it did appear that there was not a written standard for Class 1 pressure vessels. There were standards for certain parts of equipment used in the turbine industry.

We were informed that radiography was used on a wide scale, and although we did not see any equipment in action there was evidence at a shipyard that radiography of some of the welding had been done. We were informed that 20% of the ships' hulls are X-rayed which is higher than the percentage for like fabrications in this country.

The ultrasonic examination of welds did not appear to be practised generally but in one plant it was in use for examining turbine rotors. The standard allowed slag inclusions up to 1 mm long, provided that they were isolated; cracks were not allowed, and individual porosity up to 1 mm was permitted in an area of 1 sq.cm.

The quality of all welding appeared to be dependent on the successful inspection and testing of preproduction test pieces which had been welded with the techniques to be applied in production. Fabricators did not appear to test production test plates as manufacturers are required to do in the U.K.

The preparation before welding did not appear to be as carefully done as in the U.K. Although we were told that there were many machine planers in operation we did not see any at work, and in fact all the edges that were prepared for welding had been hand burnt with the exception of the plates at the shipyard, and here a very modern photo-electric-cell cutting unit was seen at work.

Welding RESEARCH

B.W.R.A. REPORT

Some Experiments in Controlled Low Temperature Stress Relief

Controlled low-temperature stress relief (the Linde Process) has been applied to welded mild steel pipes in which the transverse residual stresses were high. Stress-corrosion tests and stress analyses have indicated that such stresses may be reduced by this process.

By R. N. Parkins, B.SC., PH.D.

THE relief of residual stresses in welded structures is most effectively achieved by furnace annealing at a temperature where the yield stress of the material is reduced to about 1 ton/sq.in. or less. It is clear, however, that such treatment may not always be possible either because furnace capacity is inadequate for the size of the structure to be treated, or because of the distortion which the structure would suffer under its own weight if heated to the relatively high temperatures involved in such anneals. In these cases it may be necessary either to apply controlled heat in certain localized regions of the structure or to furnace anneal at some temperature below that at which marked distortion appears, but at which the extent of stress relief will be reduced. The present paper is concerned with some experiments on both of these approaches. They were initiated by the former FM.9 Committee of the British Welding Research Association, which was concerned with an investigation into the incidence and prevention of stress-corrosion cracking in welded mild steel structures used in the gas industry.[1,2] Such cracking may be prevented by stress relief of the structure, and furnace annealing for this purpose has become increasingly common in recent years. For certain large vessels, or where site welding is necessary, the possibility of other methods of stress relief has to be considered and it was in this context that the present experiments were carried out.

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Generation and Relief of Residual Welding Stresses

Temperature gradients introduced to a structure during welding result in differential expansion of the parent material in which the hotter zones are restrained by those at lower temperatures. If the temperature differences exceed about 150°C. the restraint may be sufficient to cause the material to be stressed to the yield point, when plastic upsetting occurs in the hotter zones in a direction normal to that of the temperature gradient. As the whole structure cools to an even temperature the inhomogeneous plastic strains cause elastic strains to be generated for reasons of compatibility. In a simple butt weld, tensile stresses of yield-point magnitude are generated parallel to the weld and for an inch or so into the parent plate, after which, in moving away from the weld, they reduce in magnitude and eventually reverse in sign.[3] Transverse stresses are also generated, but in the absence of restraint these are usually less important, being only about half the magnitude of the longitudinal stresses.

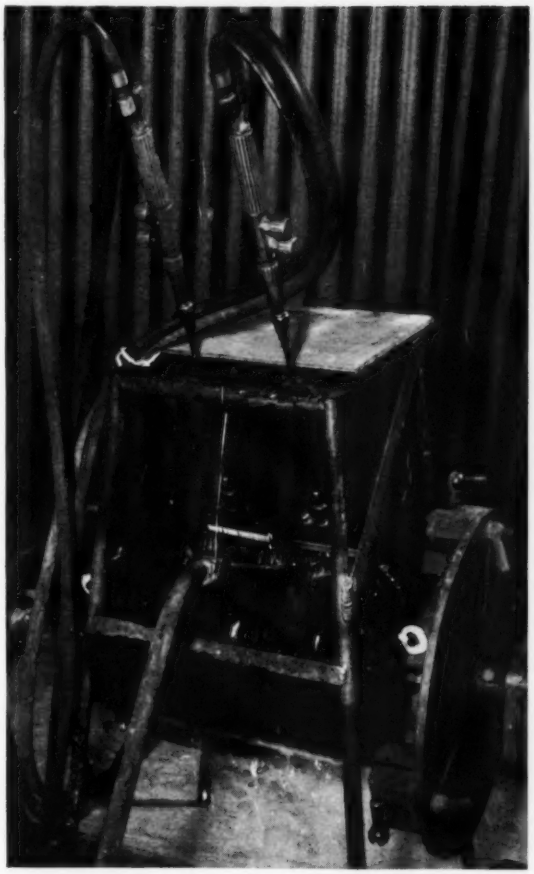
Controlled low-temperature stress relief (the Linde

Process) aims at the plastic stretching of the upset region in the immediate vicinity of a weld by the localized application of heat.[4] By heating zones immediately adjacent to those in longitudinal tension, in the case of a butt weld, a system of strains is established opposite to those developed during welding and, if the temperature differences are correctly chosen at about 200°C., appreciable stress relief may be effected. Greene and Holzbaur,[4] in giving the results of an extensive investigation into the process, have shown that the principal tensions may sometimes be reduced by about 90%. Others[5,6] have reported reductions of 60–70% in the highest residual stresses occurring in certain structures, but Gunnert[7] doubts the effectiveness of the process in reducing transverse stresses, where these are high because of welding under conditions of restraint. Certainly if the region in longitudinal tension is plastically stretched a contraction must occur in the transverse direction. This may add to the plastic compression that occurs in this direction during welding and so apparently increase the transverse stresses. In some structures the effect may be negligible, and, indeed, Greene and Holzbaur indicate a reduction in the transverse stresses as the result of controlled low-temperature treatment, but with some shapes the result may be otherwise. In the welding of cylindrical vessels of not more than a few feet in diameter, for example, the rigidity of the cylinder is appreciably greater along its length than in its circumference, as shown by the fact that the principal residual tensions run parallel to longitudinal welds but transverse to circumferential welds. It may be expected therefore, if the above argument is correct, that any attempt to relieve the tension associated with the cylindrical welds, by generating heat bands on either side of, and a little removed from, the welds, will not be successful. Since many of the structures used in gas plant are cylindrical it seemed necessary to apply the technique to this particular problem, notwithstanding published information on flat plates which shows the technique in a favourable light.

Experimental Techniques

The test pieces for the experiments were in the form of welded mild steel pipes 23 in. long, 11 in. inside diameter, and ¼ in. wall thickness. These were made by joining with a circumferential weld two 11½ in. lengths of piping, each containing a longitudinal weld. Tack welds and inside runs were deposited manually, and external runs were deposited by an open-arc process. As far as possible the welding procedure was constant for all specimens.

In the controlled low-temperature stress-relieving experiments heat was applied to the parent plate adjacent to the welds by two oxy-acetylene flame-cleaning burners from a point $\frac{7}{16}$ in. above the surface of the plate. Different temperatures were obtained by varying the rate of travel of the pipe beneath the burners and heat was applied to external surfaces only, on the assumption that the plate was sufficiently thin to conduct heat rapidly to the inside surface. The conditions required to give a particular temperature distribution were determined by trial and error on a pipe used only for this purpose, after which the same treatment was applied to each of two pipes initially in the 'as-welded' condition. Temperatures were measured with the aid of temperature-indicating crayons applied to the inside of the pipe, and the heated zone was cooled by a water spray placed 2½ in. behind the heaters. Rotational or lateral movement of the pipe was provided by equipment of the type employed in automatic welding and cutting processes. Figure 1 shows the arrangement for treating circumferential welds.



1—*Apparatus for controlled low-temperature stress relief of circumferential welds on pipes*

As well as varying the temperature differential, 3 in. and 4 in. wide burners were used in different test runs. These were arranged so that their centres were 2½ in. and 3 in. respectively from the weld, and care was taken to avoid overlapping of the heated parts of the pipe at the end of a traverse.

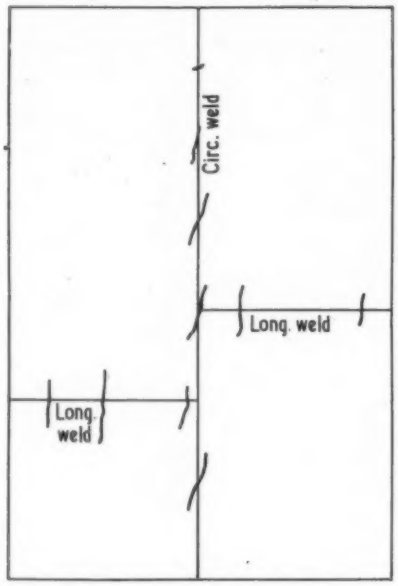
All treatments were carried out on duplicate specimens so that one could be subjected to a stress-corrosion test in a boiling nitrate solution and the other analysed for residual stresses. The stress-corrosion tests were made with the specimen contained in a mild steel tank and completely immersed in a boiling solution containing 860 g/l of calcium nitrate and 30 g/l of ammonium nitrate.[8]

Where the stresses were expected to be high and the stress gradients steep the Gunnert gauge[3] was used

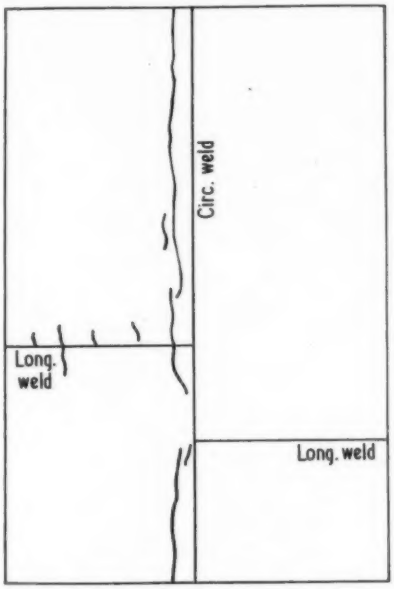
for measuring the strains relieved on cutting; elsewhere the technique developed by Soete,[9] using electrical resistance strain gauges, was employed.

Stress-Corrosion Test Results

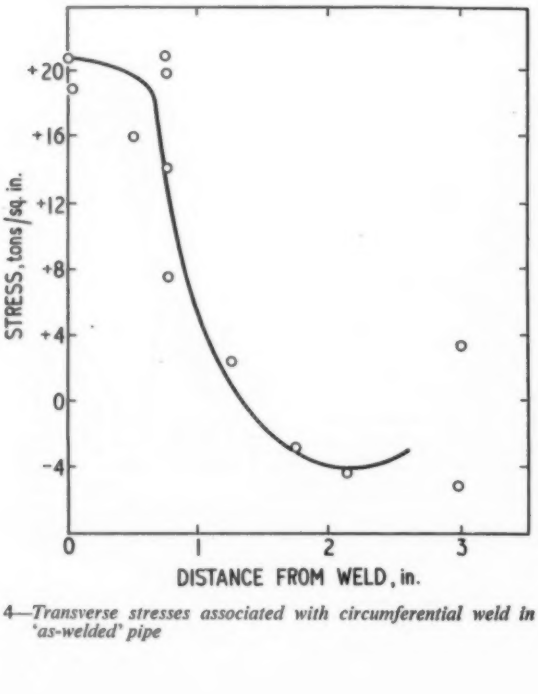
Stress-corrosion cracks are liable to develop in mild steels that are subjected to tensile stresses of about 10–20 tons/sq.in. and to certain types of corrosive environment.[8,10] The crack distribution is usually related to the residual stress pattern in welded mild steel structures, the cracks propagating normal to the directions of the principal tensions. The present tests therefore not only acted as a direct measure of the effectiveness of the various treatments in preventing stress-corrosion cracking but also showed the distribution of the high tensile stresses remaining in the treated pipes.



2—*Distribution of stress-corrosion cracks in 'as-welded' pipe (The pipe has been drawn as a flat plate for purpose of illustration)*



3—*Distribution of stress-corrosion cracks after controlled low-temperature stress relief with temperature differential of 200°C.*



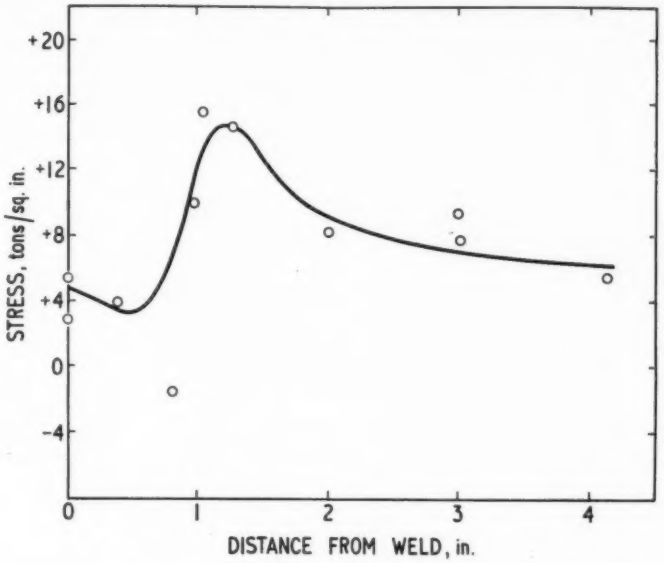
4—*Transverse stresses associated with circumferential weld in 'as-welded' pipe*

In the 'as-welded' condition the specimen showed fine cracks on the longitudinal welds when examined after 20 hr immersion, and these continued to develop with additional cracks appearing in the region of the circumferential welds, up to the time the test was discontinued (164 hr). Figure 2 shows the crack distribution at this time and indicates that the highest tensile stresses are parallel to the longitudinal welds but transverse to the circumferential weld.

For comparison some of the pipes were given typical furnace stress-relieving treatments at either 450° or 550°C. for 1 hr, or 650°C. for 4 hr. Pipes having had one or other of these treatments were subjected to the stress corrosion test but no cracks were observed during tests which lasted for 500 hr or more.

The first of the controlled low-temperature stress-relieved pipes was prepared with a temperature differential of 200°C., using 4 in. wide burners on the circumferential weld and 3 in. burners on the longitudinal welds. Cracks were apparent on the longitudinal weld, and in the heated zone of the parent plate running parallel to the circumferential weld, after 20 and 40 hr immersion respectively in the boiling nitrate solution. The cracking had developed to the extent shown in Fig. 3 after 164 hr of testing. It is clear that some

improvement resulted from treatment of the longitudinal welds but that, if anything, the cracking associated with the circumferential weld, although confined to the parent plate on one side only, was more severe than in the 'as-welded' pipe. It is noteworthy that the cracking showed that the principal tensions still ran in the lengthwise direction of the pipe and that the maximum transverse stresses associated with the circumferential weld had been moved from the weld itself to a region just within the band of low-temperature treatment on one side of the weld.



5—Transverse stresses associated with circumferential weld after controlled low-temperature stress relief with temperature differential of 200°C.

When the burner width for the circumferential weld was reduced to 3 in., and the temperature differential to 150°C., the cracks developed suggested no great improvement from the position achieved in the first test, cracking again being observed in the heated band of the parent plate adjacent to the circumferential weld.

In a third series of tests the burner widths were maintained at 3 in. and a temperature difference of 120°C. was achieved. In this case no cracks developed during a 500 hr immersion in the boiling nitrate solution.

Stress Analyses

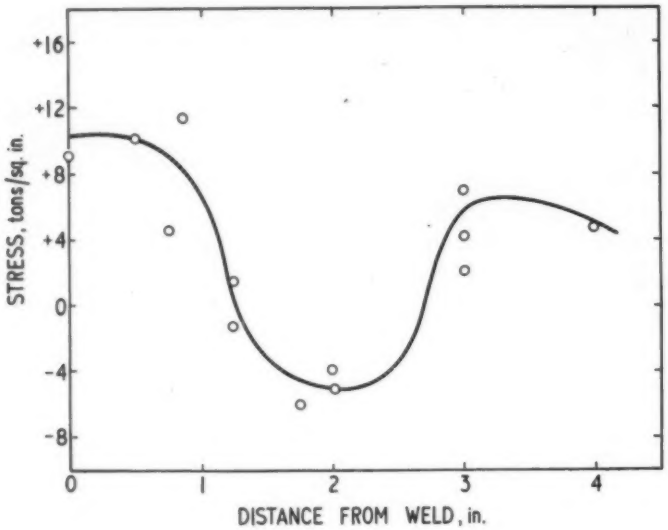
The biaxial stress systems associated with both the longitudinal and circumferential welds were determined on a number of pipes. The highest stresses in the 'as-welded' pipes, as may be expected, were those running approximately transversely to the circumferential welds; these are shown in Fig. 4. Only those points of measurement some few inches or more from the longitudinal welds have been used in this plot. The stress distribution is of the expected form, showing high tensions in the immediate vicinity of the weld, these reducing and eventually becoming compressive in moving away from the weld.

In the case of the pipe subjected to controlled low-temperature stress relief, with a temperature differential of 200°C., the high tensions near the weld in the 'as-welded' condition were reduced (Fig. 5), but at about 1 in. away from the weld and just within the heated band, the transverse tension was considerably increased. This movement of the maximum tension from the immediate vicinity of the weld to the edge of the heated band corresponds to the shift observed in the crack distribution from the stress-corrosion tests. This result is perhaps not surprising in the light of the results shown in Fig. 4, since it is clear from the latter that the heated band overlapped the region originally in transverse tension, resulting in further plastic upsetting towards the edge of the tensile zone and an increase in the tensions. Accurate knowledge of the original stress distribution is, therefore, an essential pre-requisite to stress relief by this technique.

The pipe stress relieved with a temperature differential of 150°C. showed a similar type of transverse stress distribution to that depicted in Fig. 5, with the peak stresses slightly reduced. When the temperature difference was reduced to 120°C., however, the stress pattern was as shown in Fig. 6. Here again there is just the suggestion of an increase in the transverse tensions at a distance of about 1 in. from the weld, but the maximum observed was less than for the pipes treated with temperature differentials of 200° and 150°C. The tensile stresses very near to the weld were again reduced from the high values observed in the 'as-welded' pipe, but they were not reduced so far by the treatment involving the 120°C. temperature difference as when the difference was 150° or 200°C. It would appear therefore that the 120°C. treatment was effective because, while sufficient to reduce the near-weld tensions to less than the value required for stress-corrosion cracking, it did not increase the transverse tensions in the heated band to the point where the minimum cracking stress was exceeded.

Some stress determinations were also made on the

pipes stress relieved by furnace annealing, and Fig. 7 shows the stress pattern for the pipe annealed at 450°C. The maximum residual stress measured in this pipe was about half the maximum value measured in the 'as-welded' pipe, in reasonable agreement with previous results.[2] A few measurements were made on the pipes treated at 550° and 650°C. and these showed further reductions in the level of the residual stresses.

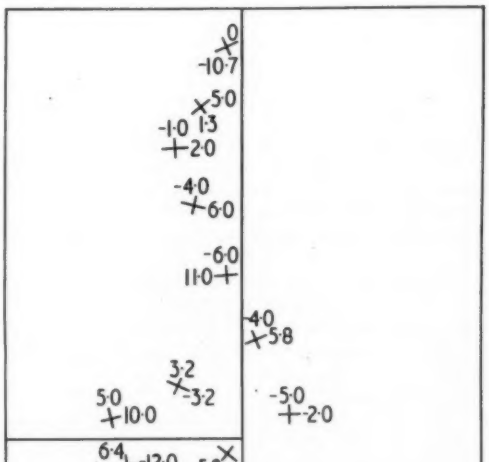


6—Transverse stresses associated with circumferential weld after controlled low-temperature stress relief with temperature differential of 120°C.

Discussion

In so far as it was possible to apply controlled low-temperature stress relief to prevent stress-corrosion cracking in a welded pipe, the series of experiments achieved one of its main objects. The measured stresses even in the best case did not indicate as large a reduction as that obtained by Greene and Holzbaur, although it may justifiably be said of the present experiments that treatment would have been carried out differently had the results of measurements on the 'as-welded' pipes been available at the start. On the other hand it may well be that the reduction in stresses was limited for the reasons put forward by Gunnert; *i.e.*, that where the principal stresses are transverse to the weld the technique is much less effective than when they are longitudinal.

In spite of Gunnert's objections to the technique for dealing with transverse stresses, the present experiments have shown, by stress analyses and the fact that the place of cracking in a stress-corrosion test could be moved, that the transverse stress pattern can be altered appreciably. It would therefore seem reasonable to conclude that, even in structures welded under restraint where transverse stresses are high, these may at least be redistributed and the peak stresses relieved. This answer lies somewhere between the extremes which some have inferred from the results of Greene and Holzbaur on the one hand, and the arguments of Gunnert on the other, and may not be surprising in view of the necessary simplifications which each has made in explaining the effect of controlled low-temperature treatments. Thus, each has assumed that the heated band attains the necessary temperature over the whole of its length at the same time; yet, in fact, the heated zone is approximately rectangular at any instant and is defined by the burner width and the distance between the burner and the water spray. The strains generated by the low-temperature heating are



7—Residual stresses in pipe furnace stress relieved at 450°C

therefore biaxial, as when the weld itself is deposited, and it would seem necessary to consider this fact in any explanation of the detailed effect of the treatment. (Since the present work has been concerned with thin plates, the question of temperature gradients through the plate has been neglected, and the objections which Gunnert has made to the technique when concerned with thick plates would not appear to apply.)

The fact that the present experiments pointed to a temperature difference of 120°C. as giving the best results, as opposed to the 200°C. recommended by Greene and Holzbaur, is presumably associated with the fact that the heated bands were located nearer the welds in the present case. This resulted in an increase in the tensile stress values at about 1 in. from the weld, but by keeping the temperature difference low a compromise was effected between this increase and the reduction in the immediate vicinity of the weld. It seems reasonable to suggest that, had the heated bands been located about $\frac{1}{2}$ in. further from the weld, a higher temperature differential could have been used and the maximum stresses probably reduced even further.

Conclusions

Controlled low-temperature stress relief can be effective in the case of pipes where the restraint is sufficient to yield high transverse stresses, although the present experiments have not indicated the reduction of stresses to very low levels. However, where the principal concern is with peak stresses the technique may be quite effective, especially if its application considered at the design stage and the probab residual welding stress pattern is known beforehand. It is clear however that there is a very real need for more experience in the application of the Linde Process and this, to be of any real value, should be backed by appropriate stress measurements.

Acknowledgments

The work was performed with the assistance of the members of the former FM.9 Committee of the British Welding Research Association and of British Oxygen Gases Ltd. (British Oxygen Co. Ltd.).

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NEW PUBLICATIONS

Esab Conference

"*Automatic Welding*" is the title of a handsomely produced volume which makes available to English readers eleven papers presented at the Esab conference in Gothenberg last April. Copies of the book are obtainable from Esab Limited, Gillingham, Kent, price 63*s*.

Standards for pressure vessels

The British Standards Institution has issued one new (B.S.3256) and two revised (B.S.4871 Part 1, and B.S.1099) specifications for pressure vessels.

The two revised standards now apply also to air receivers for use on railways and the new standard (3256) has been prepared specifically to deal with small air reservoirs for road and rail vehicles.

An outcome of the revision of B.S.487 and 1099 is that thinner scantlings are now permitted for receivers constructed of material complying with B.S.1633 (Steel for land boilers, receivers and other pressure vessels).

A feature common to all the pressure vessels dealt with in these three publications is their classification according to the material and type of construction used and to whether they are heat-treated after construction.

Copies are obtainable from B.S.I., Sales Branch, 2 Park Street, London W.1, price B.S.487 Part 1, 8*s*. 6*d*; B.S.1099 and B.S.3256, 6*s*. each.

Non-destructive Testing

A booklet '*Solus-Schall Inspection Service*' has recently been issued by Solus-Schall Ltd. to describe their facilities for site testing by non-destructive methods. These include visual welding inspection, X- and gamma-radiography, penetrants, ultrasonic and magnetic particle flaw detection.

Copies of the booklet may be obtained free of charge from the Company.

▶CIBA (A.R.L.) Ltd. of Duxford have recently published a booklet entitled "*Introduction to Duxford and to the Products of CIBA (A.R.I.)Ltd*".

▶Siemens-Schuckert (Gt. Britain) Ltd. have published a booklet on the Electrical Protection of Portable and Transportable Apparatus by means of their Earth Leakage and/or Monitored Earth Units.

▶A paper on "*A New Filler Rod for Gas-Welding of S.G. Iron*" and "*Annealing of S.G. Iron by Continuous Cooling through the Transformation Range*" was presented by R. H. T. Dixon, on behalf of The Mond Nickel Company at the 8th International Conference of S.G. Iron Licensees, at Innsbruck.

▶Eltron (London) Ltd. have issued their latest catalogue containing up-to-date information on their electric heaters.

NEWS and Announcements

News of the Institute and Branches
B.W.R.A. · Other Societies · and Industry

INSTITUTE ACTIVITIES

MEETINGS

Autumn Meeting 1960

The Presidential Address, delivered by Mr. E. Fuchs, opened the Institute's Autumn Meeting on the evening of Tuesday 1st November. In a survey, illustrated with lantern slides, Mr. Fuchs, while insisting that the requirement of industry was 'One Quality—The Best', considered that fitness for purpose must be taken into account in deciding what was best in any given circumstance if welding was to be economic. There was a large and appreciative audience of members and visitors at the Address and subsequently at a Reception at the Institute.

Welding Metallurgy

The whole of the following day was given to the presentation and discussion of ten papers on various aspects of the Metallurgy of Welding and Brazing, and to a joint meeting of the Institute and the Institution of Metallurgists, at which Mr. H. E. Dixon and Mr. M. Birkhead opened a lively discussion on "*The Role of the Metallurgist in Fabrication involving Welding*". Dr. L. B. Pfeil, O.B.E., presided over the morning session and Mr. L. Rotherham over the afternoon one, and the chair at the joint meeting was taken by Dr. N. P. Allen, senior Vice-President of the Institution of Metallurgists.

The papers (already published in *B.W.J.*) dealt mainly with metallurgical problems arising in the welding of plant for the Atomic Energy Authority, for nuclear and other power stations, and for chemical works.

Annual Dinner

The meeting closed with the Annual Dinner at the Park Lane Hotel, at which the principal guest was the Hon. Mr. Justice Lloyd-Jones, who proposed the toast of the Institute in an entertaining speech contrasting the function of welding with that which fell to him as a Judge of the Probate, Divorce and Admiralty Division of the High Court.

In his response, the President, Mr. E. Fuchs spoke of the educational activities of the Institute and referred to the forthcoming post-graduate course in welding at the College of Aeronautics, Cranfield.

He also expressed the thanks of the Council to the 300 or more lecturers at the School of Welding Technology whose efforts had contributed so much to the success of this educational venture. The toast of the guests was proposed by Mr. W. E. Harriss, Honorary Treasurer of the Institute, and the response was given by Mr. G. A. J. Begg of Imperial Chemical Industries Ltd.

Conference on Welding Standardization

The First Annual Conference on Welding Standardization was held at the Institute on Wednesday, 7th December 1960, and was opened by the Secretary of the Institute, Mr. G. Parsloe. There were three sessions: National and International Standardization; Standards for Carbon and Alloy Steels; and Standards for Welded Bridges, Structures, and Cranes. The Chairmen were Mr. G. Parsloe, Mr. J. A. Dorrat, and Mr. L. R. Creasy. Opening speeches were made by Mr. R. A. McKinstry, Mr. J. F. Pearson, Mr. H. F. Tremlett, Mr. O. A. Kerensky and Mr. A. J. Elliott, followed by discussions, a fuller report of which will appear in the next issue of the *Journal*.

Welded Maidenhead Bridge

Mr. Gilbert Roberts will read a paper on the welded Maidenhead Bridge at a joint meeting of the Institute and the South London Branch on Wednesday, 8th February 1961 at 7 p.m. Admission will be by ticket to be had from the Secretary of the Institute.

Spring Meeting 1961

The Spring Meeting of the Institute, which will open with the Fourth Annual Lecture and a Reception at the Institute on the evening of Monday, 24th April next, will be devoted to *Recent Developments in the Welding and Allied Processes and in Heat Treatment*.

The Annual Lecture will be on *Welding in the Non-Ferrous Field* and will be given by Dr. N. P. Inglis.

Among the papers which have been promised are:

Use of Gas Mixtures in Gas-Shielded Bare Wire Welding
Development of Automatic Tungsten Arc Welding of Heat Exchangers
Electrical Heat Treatment for the Preheating and Stress Relieving of Welds
Infinitely Variable Arc Welder (using a new form of control other than moving chokes or transductors)
Recent Developments in Brazing
Recent Developments in the Metal Spraying Processes

Discussions will be held on the mornings of Tuesday 25th to Thursday 27th April 1960, and there will be a visit to the welded Maidenhead Bridge on one afternoon.

The joint London Branches Dinner is being held on the evening of Thursday, 27th April, and members attending the Spring Meeting will be able to obtain tickets.

It is expected that the official visit to the Engineering, Marine, Welding and Nuclear Energy Exhibition will take place on one of the days of the Spring Meeting.

Joint Meeting with the Netherlands Welding Society

The Netherlands Welding Society has invited members of the Institute of Welding to a joint meeting to be held in Utrecht from 31st May to 2nd June 1961, for the presentation and discussion of a number of papers on *Aluminium and its Alloys*.

The programme will include three sessions for the presentation and discussion of the papers, a visit to the

Welding Exhibition organized by the Netherlands Welding Society and, on the concluding day, a choice of works visits.

The enrolment fee for members of the Institute will be 25 florins. The only other charges will be for luncheons and transport. Visitors will be the guests of the Netherlands Welding Society at a reception and a dinner.

Members of the Institute who are interested are asked to apply to the Secretary for copies of the full programme and enrolment form.

Autumn Meeting 1961

Symposium on Welding in Shipbuilding

The Royal Institution of Naval Architects, the Institution of Engineers and Shipbuilders in Scotland, and the North East Coast Institution of Engineers and Shipbuilders have agreed to co-operate with the Institute of Welding in a Joint Symposium on Welding in Shipbuilding, to be held in London in the week beginning on 31st October 1961.

The Joint Committee hopes to receive offers of papers on:

Structural Design of Welded Hulls
Building of Welded Ships
Shipyard Layout for Welded Shipbuilding
Automatic Welding in Shipbuilding
Materials Handling
Welded Joints in Thick Mild Steels
Use of High Yield Point Steels in Welded Ship Construction
Aluminium Alloys for Welded Ship Construction
Non-destructive Testing of Ship Welds
Training and Testing of Ship Welders

All papers accepted by the Joint Organizing Committee will be preprinted and subsequently published with the Discussion in a volume of Proceedings.

Spring Meeting 1962

Welding for Power Generation

The theme of the Spring Meeting of 1962 which is to be held at Buxton from 1st to 3rd May, will be *Welding for Power Generation*. The following are examples of subjects on which it is hoped that papers will be offered, and members who would be willing to contribute papers on these or other subjects within the main theme are invited to send particulars to the Secretary before the end of March 1961.

Welding of boiler plant, headers, superheaters, etc., including nuclear heat exchangers
Welding of turbine and ancillary plant, including water turbines, cylinder casings, steam chests, valves, pumps, etc.
Pipework
Reactor pressure circuits including the pressure vessel, ducting, bellows units, etc.
Welding of rotors and shafts in turbo-alternators, water wheel alternators, etc.
Construction of tanks for transformers and switchgear
Welding of feed heaters and condensing plant
Welding of thick plate and sections
Suitability of new welding techniques and processes for power plant
Training of welders for Class I vessels
Inspection of welded plant by non-destructive methods
Welding in the fabrication of fuel elements including uranium, beryllium, zirconium, niobium, etc.
Welding in the repair and maintenance of power stations.

TIBBENHAM PRIZES

This year's winners of the Tibbenham Prizes, which were endowed by Mr. L. J. Tibbenham and are awarded by the Institute on the results of the welding examinations of the City & Guilds of London Institute are:

1st Prize: Stanley Albert Dye—Age 30—An Experimental Officer who was examined at Tottenham Technical College

2nd Prize: Raymond Alfred Collins—Age 32—Welder. A student of Matthew Boulton Technical College, Birmingham.

Welding Technology Course

The prospectus for the Post-Graduate Course in Welding Technology, which is to be opened at the College of Aeronautics, Cranfield, in the autumn of 1961, was distributed last month to member-companies of the Institute and the B.W.R.A., in response to whose representations the Ministry of Education has established the course. The prospectus has also been distributed very widely to industry and to the technical press.

The course will last for three academic terms extending over nine months. Students who wish can spend a further three months in project work.

The course is designed to equip engineers and metallurgists as welding specialists, and will lead to a Diploma in advanced Engineering (Welding). The fees will be about £45 a term inclusive of residence.

Members of the Institute are invited to apply to the Secretary for copies of the prospectus.

PUBLICATIONS

List of Members

The first issue of the List of Members of the Institute was distributed to corporate members last month.

I.I.W. Publications

The attention of members is drawn to the following I.I.W. documents recently published in this country by the Institute and obtainable from 54 Princes Gate, Exhibition Road, London S.W.7.

Comparison of Brittle Fracture Tests, a Report of Sub-Commission 'A' of Commission IX (Behaviour of Metals subjected to Welding). Price 5*s*. including postage.

Recommended Welded Connexions for Pressure Vessels, a Report of Sub-Commission 'A' of Commission XI (Pressure Vessels, Boilers and Pipelines). Price 4*s* 6*d* including postage.

The Institute is about to publish on behalf of the International Institute of Welding a *Handbook of Radiographic Apparatus and Techniques*, for which a separate announcement will be found in the advertisement pages.

NEWS OF MEMBERS

Mr. F. D. Duffin has been appointed Chief Inspector at the Hughes Tool Co. Ltd., Belfast.

Mr. H. D. Baer has been appointed Sales Manager of the resistance welding electrodes department of Enfield Rolling Mills Ltd. He succeeds **Mr. W. J. Armstrong**, who has moved to a production post in the drawn copper department.

Mr. E. V. Beatson of Joseph Lucas Ltd. has been appointed by the Council of the British Welding Research Association to serve on the Association's Research Board.

Mr. J. Williams (representative of I.C.M.) has been appointed a Local Director of Samuel Osborn & Co. Ltd., Sheffield.

Obituary

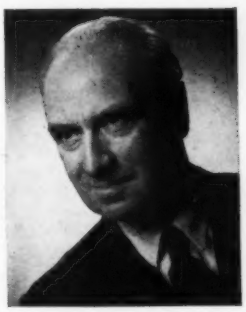
The Council records with regret the deaths of the following members:

Mr. J. Miller-Watt, on 1st May 1960 (Associate 1944).

Mr. W. F. Hope, in August 1960 (Associate Member, 1942).

CONTRIBUTORS TO THE JOURNAL

J. A. Dorrat, A.H.W.C., M.I.E.E., M.Inst.W., who is welding engineer to



the Richardsons Westgarth Group, received his technical education at

Heriot Watt College, Edinburgh, and joined the Metropolitan-Vickers Electrical Company as a college apprentice. He gained experience in research, design and production before taking part in the sudden increase in welding activities about 1930. His work there covered all fields of welding, from design and manufacture of fabrications to the equipment necessary for their production, and included a visit to America.

Mr. Dorrat joined Richardsons, Westgarth & Co. Ltd., in 1943, and was introduced to marine engineering in frigates, corvettes, and all types of cargo ships, with both diesel and turbine machinery installations. He visited America wjth the Welding Productivity Team in 1950 and subsequently went to Holland, Germany, and Switzerland.

He is a member of the British Standards Institution Welding Industry Committee and of the Council of the Institute of Welding, being Chairman of its Technical Committee. He has lectured extensively throughout the country to technical societies at summer schools and at post-graduate courses in various colleges.

BRANCH NEWS

East Midlands — Annual Dinner

The Branch held its annual Dinner at the Victoria Station Hotel on Monday, 17th October. The Branch Chairman, Mr. L. Padmore, was in the chair. The Toast of the Institute and its East Midlands Branch was proposed by Mr. J. Leather, Principal of Newark Technical College, and the response was made by the President of the Institute, Mr. E. Fuchs. Both speakers dwelt upon the place of welding in the education of engineers, and the President called for the support of all members in ensuring that the post-graduate course in welding technology, which is to be offered next Autumn at the College of Aeronautics, Cranfield, would attract a full enrolment from industry and from technical college teachers.

The President of the Branch, Mr. H. L. Palmer, proposed the Toast of the Guests, and the response was made by Mr. G. Parsloe, Secretary of the Institute.

East of Scotland — Chairman's Address

The Chairman, Mr. J. F. Wheeldon, opened his Address on 19th October with a preview of the 1960–61 syllabus, which he, the office bearers, and members of the committee had compiled. He was confident that the new season would prove to be one of interesting lectures, films, and visits.

He also expressed the hope that the Branch would receive the full co-operation of all present members; more new members would be welcomed, and at the future meetings anybody with interests in welding should come along with their problems and join in the debates.

The main theme of the Chairman's Address was "*Co-ordination between management, supervision, and the operator*", and the speaker gave his views mainly as applied to a small-size firm (one of which he is himself the Managing Director).

The talk touched on fabrication work, from the initial enquiry to the finished article ready for despatch. Stress was placed on the co-operation between the estimator and the shop-supervision regarding methods of assembly, material preparation, type of electrodes; weld preparation, piecework prices, and so on, and the need for the full specifications and information to be passed to the man on the shop floor.

Mention was made of the method of making up the cost of fabrications and how design, handling, and shop planning also play a vital part. In all, the Address was most interesting as was proved by the constructive discussion at the end.

Mr. J. C. Adam wound up the debate with a vote of thanks to Mr. Wheeldon and hearty appreciation was shown.

B.T.

Manchester — Weld Quality

Bolton Municipal Technical College was the venue chosen for Mr. Colin Spencer to present his paper entitled "*Mastering imperfections by a code of good welding practice*", on Wednesday 19th October, 1960. This 'extra' meeting was well supported by the officers, committee and members of the Branch and also by students of the College and guests.

Mr. Spencer opened stating that he felt that imperfections in welding emanate from either poor quality material or bad plate preparations. He said that he had been privileged to see nearly every type of English and German cutting machine actually being manufactured. He referred to electronically controlled computer machines operating from a specially prepared tape and to a recent visit made to a company in Sweden as their guest. During the trip to Scandinavia he was shown a flame-cutting machine of the very latest design where the tracing is done from a negative reduced to one tenth the size of the drawing, which in turn was one tenth the actual size of the required profile. These machines are manufactured in Germany and were seen operating in the Eriksberg Shipyard, where units of up to 100 tons weight are prefabricated.

Mr. Spencer went on to describe and illustrate by slides the welding shop lay-out in his own Company. He explained how they give very special attention to the metallurgical aspect of flame-cut mild steel material and also reduce the possibility of notching to a minimum. Special care is taken in cleaning off scale, hydrated rust and even surface rust, and careful thought is given to the type of cutting nozzle used. Handling of material and units, and use of positioners are all very important factors in overcoming the possible occurrence of imperfections. Mr. Spencer quoted various special products of his Company and instanced problems experienced and how they had been overcome.

In conclusion he emphasized that suspect welding must not be permitted and that, with so much technical knowledge available today, all concerned must master imperfections by a code of good welding practice.

The proceedings ended with a vote of thanks to Mr. Colin Spencer proposed by Mr. J. W. Addie.

A.C.M.

North London — Welding Heavy Plate

For the second meeting of the session, held on Wednesday 19th October, Mr. J. A. Lucey took the place of Mr. T. S. McNeish at short notice. In his lecture on "*Automatic welding of pressure vessels and heavy plate*" Mr. Lucey reviewed the processes available for the welding of such constructions in thick material. The fundamentals of edge preparation were discussed in some detail and emphasis was placed on the need for attention to every detail if first-class results were to be produced first time.

The effects of distortion were well illustrated with animated sketches. A series of slides showing typical welded sections, equipment used, and a number of interesting applications proved most instructive.

Mr. Lucey concluded his lecture by dealing with the electro-slag process, which again was illustrated with slides.

A lively discussion followed between the speaker and some of the 70 members present and, in particular, there was interest in the problem of distortion and its control by practical methods.

F.W.C.

Sheffield — Works Visit

The Winter Programme commenced on 16th September 1960, with a visit to the Works of Messrs. Newton Chambers & Co. Ltd., Thorncliffe, Chapeltown, by kind permission of the Chairman and Directors. The visit was organized by the Branch Chairman, Mr. S. B. Rippon, J.P., who unfortunately could not be present, owing to a business trip to America.

The party consisted of 60 members and friends, who were met at the Main Office and welcomed by Mr. F. Whitehouse, and were then split into smaller groups, each with a very capable guide. First they were taken to the Exhibition Hall, where with the aid of models and photographs the history of the firm and its products were clearly explained. Motor coaches were used to take the visitors from one Department to another.

The foundries were first visited, where it was noted that the conveyor system of production was put to full use. In the Welding Shop visitors saw profile machines in use and various sections of excavators being fabricated. Also in the Construction Shop, fabrication was in full swing, being used on a variety of pressure vessels, including Class 1. This really did 'wet the appetite' of the members.

Next came the Excavator Division, the visitors passing through the Paint Shops, Machine Shops, Assembly lines and later to the Test Field where it appeared that the only wish of the Inspector in Charge was to break the excavator on test if he possibly could. Again the members were amazed at the punishment given to these machines.

A further surprise was in store when the members were taken to the Managers' Dining Rooms for tea, which was most welcome and excellently served. Following the excellent meal provided, a vote of thanks was proposed to the Chairman and Directors and was supported with great enthusiasm.

After tea a paper "*Welding procedure and job testing*" was presented in the Lecture Hall by Mr. W. J. Colton, F.I.M., A.M.I.Mech.E., a member of Newton Chambers' Staff and also a member of the Sheffield & District Branch. Many slides were shown to illustrate the subject, with which Mr. Colton dealt very thoroughly and a discussion followed which cleared up outstanding questions.

The visit was pleasant, informative and most enjoyable. All members received a gift of the Company's products. The Committee warmly thank the Chairman and Directors of Messrs. Newton Chambers & Co. Ltd., the Branch Chairman and all the Staff who helped to make this an interesting and enjoyable visit.

Training for welding

For the second meeting of the Session, a visit was made to Sheffield College of Technology, by kind permission of Mr. H. W. Hodson, B.Eng., M.I.Mech.E., M.I.Prod.E., Head of the Department of Engineering. Mr. Hodson conducted the members through the Engineering Section and then to the Welding Section, which is considered to be one of the finest in the country. Here the members showed great interest, for City & Guilds classes in arc and gas welding were in progress. Mr. Hodson later read a paper entitled "*Educating the technician*", explaining that there could be training for welding engineers, welding technicians, and operators. The courses should cover welding technology, metallurgy, design, inspection, education and training, and a detailed course and curriculum was explained.

Course for Technicians

The curriculum for such a course should include:

1. Mathematics of the useful kind
2. Physics (Heat and Electricity)
3. Mechanics (Statics, Dynamics, Strength of Materials and Structures)
4. Drawing
5. Chemistry
6. Metallurgy
7. Welding processes and technology
8. Welding equipment and plant
9. Design of welded fabrication and structures
10. Inspection and testing of welds
11. Assembly and erection (including jigs and fixtures)
12. Safety and protection
13. Method and work study
14. Production planning
15. Costing and estimating
16. Supervision and organization of welding
17. Development and research
18. Education and training
19. Consumer advice and service

Mr. Hodson also gave what he considered to be the necessary qualifications for welding technicians:

Qualifications for Welding Technicians

(*A*) An Ordinary plus Higher National Certificate Course to take 3 plus 2= 5 years with additional endorsements gained over 3 years could be set up leading to exemption from *revised* educational requirements of the Institute of Welding.

(*B*) An even better Course for such men would be a Sandwich Course taking 4 years, each consisting of six months in a College of Technology sandwiched between six months of properly integrated industrial experience.

Such a course should lead to a Higher National Diploma and cover the whole field of the curriculum specified above. Entry would be open at 18 years or more to those with

(*a*) A good Ordinary Certificate in Mechanical Engineering or Metallurgy, or

(*b*) G.C.E. in 5 subjects including Mathematics or Physics at Advanced level (both having been studied to A level)

Such courses could be run at a limited number of Regional Colleges of Technology suitably equipped and staffed. Sheffield is one such College.

Question time, it is believed, was the longest on record for a Branch Meeting, which proved beyond doubt the amount of interest such a visit and lecture created.

We are very grateful to Mr. Hodson for his kindness in personally conducting the visit, and for his forthright speaking on a difficult subject.

W.S.A.

Southern Counties — Welding Austenitic Steels

Mr. R. E. G. Weddell deputised for the President at the opening meeting of the session at the Technical College, Southampton, on 20th October, when there was a large audience to listen to Mr. J. A. McWilliam, T.D., lecturing on "*The welding of austenitic corrosion-resisting steels*".

The chair was taken by the Branch Chairman, Mr. C. B. Powell, and in the audience were representatives of local industry, who had been invited to meet Mr. Weddell and the Secretary of the Institute before the meeting. Among them were: Mr. Lee (C.P.C. (Southampton) Ltd.); Mr. A. F. Moseley (A.E.C. Sales Ltd.); Mr. F. T. West (Principal, Technical College, Southampton); Dr. Frank Mayo (Esso Petroleum Company); Mr. W. J. Taylor (Harland and Wolff, Ltd.); Mr. R. G. Bunce (Pirelli-General Cable Works Ltd.); Mr. G. W. Manley (C.E.G.B., Southampton); Mr. L. Hopwood, Mr. Jenkins and Mr. Hurley (C.E.G.B., Poole); Mr. Burgess (Southern Gas Board, Southampton).

During his address to the Branch Mr. Weddell said that industry was growing very quickly in the counties of Sussex, Hampshire and Dorset and the growth of industry in these days must be the growth of welding. So the Branch had to grow in numbers, in technical standards and in its influence in the life of the Institute of Welding as a whole.

The development of welding technology in the last 25 years had been remarkable by any standards. Before the war there were but three welding processes—in his Presidential Address to the Institute two years ago, Mr. Strong said there were then 50 and that one or two new ones appear nearly every year.

Since the Institute set up the Welding Research Council (now the British Welding Research Association) the body of exact knowledge about the use of these processes, about the design requirements, the techniques of welding, the methods of inspection and testing had multiplied many times.

The Institute was convinced that the development of welding technology had

outrun welding education in this country; the greatest single hindrance to the efficient use of welding in industry was the lack of engineers and metallurgists who were really knowledgeable about welding processes. The Institute was the only body in Britain which had really dealt with this acute shortage of qualified welding technologists; its meetings, publications, library and information service, and School of Welding Technology aimed at putting into the hands of the men who could use it the knowledge of welding technology collected from research and experience all over the world.

Next year, as a result of representations by the Institute and the British Welding Research Association, the Ministry of Education was to start at Cranfield a one-year residential postgraduate course in welding technology. The course would be supported by industrialists and probably by some technical college teachers, so that gradually there would be built up a body of welding specialists in industry who had been thoroughly grounded in the technology of welding. There were also schemes to bring welding into its proper place as an endorsement subject in the courses for higher national certificates and higher national diplomas, and other proposals that would give to all engineers that elementary knowledge of the possibilities and limitations of welding which they should have.

Mr. Weddell made a plea to the industrialists and to management generally to encourage their technical men to join the Institute and to see that they gained what they needed but also that they put something into it; in personal service, in the writing of papers, in lecturing in the School of Welding Technology. Many other countries were ahead of Britain in their use of welding and we simply could not afford in engineering to lag behind such countries as the USSR and the USA. All over the world our engineering products had to compete with welded products from other countries which had in some cases a 30 years' start in the training and education of welding technologists. The Institute had done an immense work and it could do still more, but this would depend in the end on what support it received from the engineering industries.

In introducing the lecturer, Mr Weddell remarked that, unlike the previous occasion when he and Mr. McWilliam appeared on the same platform, he was not able on this occasion to present to him the Harvey Shacklock Medal of the South African Institute of Welding.

Mr. McWilliam showed a wonderful range of slides illustrating the varied applications of the corrosion-resisting steels to welded fabrication.

G.P.

South Western — Power Sources

The first meeting of the new session was held at Radiant House, Bristol, on Monday 10th October, when Mr. G. C. Poxon presented a most interesting talk on "*Arc welding power sources*". At the Committee's request the subject was not treated in a highly technical manner, for it was considered that members would be more interested in general principles.

Mr. Poxon commenced by explaining simply such terms as kilowatt, kilovolt, reactance, power factor, and so on. He then proceeded, with the aid of slides, to 'take the lid off' the arc-welding transformer and current regulator, explaining the purpose and functions of the interior electrical components. A similar treatment was then given to a.c. and d.c. welding generators and transformer rectifier sets. A particular feature of this part of the lecture was that each slide showing components within the power source was followed by an illustration of the circuit diagram, thus fully conveying the principles involved to the minds of those present. Mr. Poxon also explained the different methods of controlling the current flowing in the welding circuit, as for example the moving core and the tapped choke of the a.c. transformer, and the magnetic amplifier of the rectifier set. He also high-lighted the stringent safety regulations relating to electric arc-welding plant, mentioned in BS. 638. This was followed with a discussion on the development of rectifier sets, with an explanation of the advantages and disadvantages of the use of selenium, germanium, and silicon for rectification purposes. Samples of silicon diodes were shown. The lecture was concluded with a brief outline of volt/ampere output characteristics, and the terms drooping, flat, rising, and slope-controlled were explained.

During the following discussion, Mr. Poxon ably dealt with a variety of questions, such as the intricacies of inherent rectification in the a.c. arc of the argon-arc welding power circuit, and the development of the new slope-controlled rectifier.

The lecture room at Radiant House was packed with members and friends, and this in itself was a measure of the interest shown in arc-welding power sources, a subject difficult to understand and to lecture on, but presented by the author in a simple and attractively interesting manner.

E.M.W.

West of Scotland — Radiography

The first General Meeting of the session was held at the Institute of Engineers and Shipbuilders, Glasgow, on Wednesday, 19th October, under the chairmanship of Mr. J. E. Roberts. A paper entitled "*Weld radiography*" was presented by Mr. E. J. Grimwade.

The speaker began by outlining the history of X-ray techniques since their discovery by Roentgen in 1896, and mentioned that radiographic inspection of welds had been a code requirement for 30 years. In many cases radiography is now regarded as part of the manufacturing programme and has to be planned at the design stage. Mr. Grimwade described the properties of the radiations and explained how X-rays were produced. Types of X-ray set were illustrated and radioactive sources were dealt with from the standpoint of their manufacture, properties, and usage. The relative advantages of X-ray and gamma-ray processes were enumerated in relation to their penetrating power, portability, and results obtainable. Sources of radiation are always of finite size and this inevitably causes penumbra round the radiographic shadow.

This factor, coupled with the effects of exposure geometry on radiographic definition, led the subject of sensitivity. The devices for measuring sensitivity are known as penetrameters although a better name for them would be image quality indicators. It is important that the penetrameter should be correctly place in relation to the weld, and careful marking out and film identification by lead letters is therefore necessary. Mr. Grimwade described various types of penetrameter and pointed out their limitations. He also explained the importance of adequate film density and proper illumination for viewing radiographs.

There are four main types of film commonly used for weld radiography. The types which can be used with a salt screen need only a short exposure because the fluorescence of the screen causes a more rapid activation of the emulsion chemicals. The other types are more usually used with lead foil screens and have a progressively finer grain which gives improved definition and sensitivity although longer exposures are necessary. Some excellent slides illustrated the variations in quality obtainable with these films.

Mr. Grimwade then dealt with the interpretation of radiographs. It is necessary to identify all the shadows or images which appear on the negative and to decide whether they are internal defects, surface imperfections, or spurious markings that have arisen during the film processing. The types of defect which may be found in welds are listed in BS. 499.

Mr. Grimwade concluded by saying that radiography is only one tool among many available for non-destructive examination. Each tool has a particular use and it is wrong to consider that any one is better than another. The talk was an excellent review of an extensive subject and it was given in an energetic and

entertaining manner. Questions in the discussion were very ably answered and a well-supported vote of thanks was proposed by Mr. H. Martin.

H.H.M.

Wolverhampton **Technical Reports**

There was a full house when the Chairman, Mr. E. J. Mitchell, addressed the opening technical meeting of the 1960/61 Session on 19th October, 1960. Among those present were the President of the Branch, Mr. J. H. N. Thompson, and the retiring Chairman, Mr. S. K. Stokes, who presented Mr. Mitchell with his chain of office.

Many of those present had possibly expected a highly technical treatise on some abstruse metallurgical topic, or news of the latest advances in our knowledge of electrodes and associated problems. However, a surprise was in store, for Mr. Mitchell chose to give us his views on how technical matter should be "put over" with particular reference to the writing of technical reports for the consumption of non-technical superiors.

During his discourse Mr. Mitchell criticised technical college teachers. Often they were not prepared to learn the art of clear expression themselves and hence students were set a bad example. In addition, the correction of students' work was usually related solely to the technical matter and not to its presentation or to the use of correct English. As a result of this, Mr. Mitchell felt that many industrial investigators failed to put over the knowledge they acquired in a sufficiently impressive or effective manner, and hence there was a tendency both for the reader and the investigator to lose interest.

The reader should not be plagued with a mass of mathematical formulae or with specialist language, and Mr. Mitchell quoted some examples of pompous classical names sometimes used for common botanical specimens. He also gave examples of superfluous verbosity —a disease which the writer of these notes has been accused of on more than one occasion!

Indeed, if this column continues much more, the Hon. Secretary will not be left with space for his notes, so we must come to a close, but not before mentioning Mr. Mitchell's quotation of Dr. J. W. Jenkins who said "*Words . . . are the tools we must use most and they deserve the workmanlike finish we seek in our products*".

Mr. M. R. Liddiat proposed a hearty vote of thanks expressed in a few carefully chosen words and after giving this unanimous support, the members present withdrew to the bar where it soon became obvious that their loquacity was undiminished by Mr. Mitchell's most enjoyable and interesting talk.

B.K.B.

NEWS FROM INDUSTRY

Stress-relieving furnace

A large and modern 'top-hat' stress-relieving furnace has recently been installed at the Glasgow boiler works of John Thompson (Wilson Boilers) Ltd. The furnace has a maximum load size of $17 \times 11 \times 11$ ft and it can thus handle boilers and pressure vessels up to 11 ft dia. The maximum loading weight is 15 tons, but this can be exceeded if the heat-treatment cycle can be extended beyond 12 hr. The normal cycle is 9 hr to 650°C. with a 1–3 hr soak, followed by 12 hr natural cooling.

The new furnace was designed and constructed by Shelley Electric Furnaces Ltd., in co-operation with the South of Scotland Electricity Board. It has a loading of 360 kW and the heating elements are fitted on all four sides and at top and bottom, to ensure uniformity of temperature with all types of load. Control is fully automatic after the initial setting and starting up.

The hearth has been built as a bogie for convenience in crane loading in either of two bays. The furnace is then pushed into a third bay where it automatically engages the electrical supply.

Swiss firm order British automatic welding equipment

Messrs. Sulzer Bros. of Winterthur, Switzerland, have ordered from Quasi-Arc Ltd. (British Oxygen Co. Ltd.), Bilston, a complete automatic welding installation for the fabrication of "penstock" pipes, which vary between 16 in. and 8 ft in diameter.

The installation will produce all the internal and external longitudinal and circumferential seams, in pipe sections up to 13 ft long, weighing up to 6 tons. It consists of three main units: a fixed internal welding boom; a fixed cantilever for external welding; and a mounted traversing roller bed for supporting the pipe lengths.

A special feature of the equipment is the use of a closed circuit television system for observation of the welding process when welding internally on small diameter pipes (see *B.W.J.*, Oct. 1958, p. 459).

The internal welding boom can be raised and lowered electrically to suit different diameter pipes, and it carries two Quasi-Arc welding heads arranged for the Unionmelt multi-power submerged-arc process. The boom also carries the hopper for the flux powder, as well as the television camera and necessary floodlighting equipment. The welding heads may alternatively be arranged for Unionmelt parallel electrode welding, or for gas shielded welding using a single bare wire electrode.

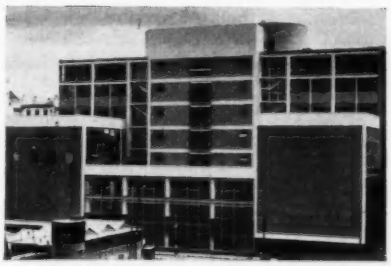
The cantilever welding machine carries two similar heads arranged for multi-power welding of external seams. A platform mounted on the cantilever provides the operator with good access to the point of weld and to the control panel on the cantilever arm. The vertical column is a rigid box section provided with machined slideways to ensure smooth motion of the cantilever arm.

The a.c. power supply equipment for each machine consists of two 1,000-amp Scott-connected transformers with associated power factor correction capacitors and contactor cubicles.

City and Guilds College

A reception was held at the Imperial College of Science and Technology on 4th November last to mark the coming into use of the first section of the new building for the Department of Mechanical Engineering. The Chairman of the Governors, Viscount Falmouth, presided and received the guests, with Mr. A. M. Holbein, C.B.E., Chairman of the Delegacy of the City and Guilds College, Sir Patrick Linstead, C.B.E., F.R.S., Rector of the Imperial College, and Professor O. A. Saunders, F.R.S., Dean of the City and Guilds College, all of whom spoke briefly explaining the plans for the development of the college. Visitors were privileged to inspect this first instalment of the new building, which will be completed some three or four years hence.

The completed building will take the place of the old buildings in Exhibition Road, which will be progressively demolished to make room for it. It will be 440 ft long, and on nine floor levels, and will provide teaching and research facilities for more than 350 students of Mechanical Engineering and for some 300 of the engineering students from other Departments of the College.



New section of the Mechanical Engineering block at Imperial College

As well as major groups working on Applied Thermodynamics and Applied Mechanics the Department also includes sections studying nuclear power and production engineering.

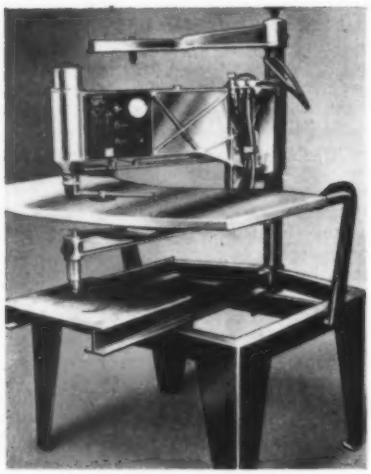
Midland Welding Exhibition

The first exhibition of Rowen-Arc equipment in the Midlands was held at

the Midlands Electricity Board Showroom, Aston, Birmingham, from 31st October to 18th November.

In addition to displays of automatic and semi-automatic welding equipment there were demonstrations of the apparatus in use.

One of the new machines featured was the four-process Rowen-Gloor flame cutter, which provides facilities for profiling from templates or drawings, straight-line cutting, and circle cutting. Adjustments are simple for changing from one form of cut to another, and a special device facilitates the production of sharp corners during profiling.



Rowen-Gloor four-purpose flame cutting machine

The complete drive unit includes a magnetic roller which follows the profile of a sheet metal template automatically.

Being adjustable vertically, it can also follow the inner contours, and the direction of rotation of this magnetic roller can be reversed, to follow a template shape in either direction.

A tracing pin enables a drawing to be followed by manual control, and a built-in device enables a 90° change of direction to produce accurate square corners.

Two special features include a parallel guide incorporating locking arms which enable straight line cutting to be made without a template. Accurate circles can be cut by use of a compass beam attached to the wheel head, permitting any diameter to be pre-set using the scale engraved on the beam.

The flame-cutter itself is designed for use with oxy-acetylene, oxy-propane or oxy-coal gas.

Another new piece of equipment being demonstrated was the Convert-Arc unit used for semi-automatic argonarc welding. This enables conventional motor-generator or transformer/rectifier power sources to be used for semi-automatic argonarc welding.

Centenary

Messrs. Sandberg, Consulting and Inspection Engineers, founded by C. P. Sandberg in London in 1860, celebrated their Centenary from 4th to 9th December last by throwing the house at 40 Grosvenor Gardens, with its laboratories and workshops, open to a large number of guests at a series of receptions.

STUB ENDS

▶Head Wrightson Stockton Forge Ltd., a subsidiary of Head Wrightson and Co. Ltd., has changed its name to Head Wrightson Stockton Ltd.

▶Mr. C. M. Stoch has been appointed Assistant Director of Research of the British Steel Castings Research Association.

▶The National Spastics Society is planning to build a sheltered workshop in Birmingham to train and employ 120 adult spastics. Facilities will include welding and sheet metal work.

DIARY

3rd Jan.—Inst. Struct. Engineers—"*Design of Welded Plate Girders*" by O. A. Kerensky (Cleveland Scientific and Technical Institute, Middlesbrough, 6.30 p.m.)

4th Jan.—Manchester—"*Pipeline Welding*" by R. J. Wright (Reynolds Hall, College of Science and Technology, Manchester, 7.15 p.m.)

5th Jan.—Institute of Welding—Second Annual Lecture for Young People, by Prof. J. G. Ball (54 Princes Gate, S.W.7., 11.0 a.m.)

N. E. Tyneside—"*Some Special Applications of Welding in Steam, Gas Turbine, and Nuclear Power Plants*" by Dr. J. M. Robertson (Mining Institute, Newcastle, 7.0 p.m.)

9th Jan.—N. E. Tees-side—"*Weld Interpretation by Radiographic Methods*" by T. W. Brown (Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, 7.30 p.m.)

Sheffield—Annual Branch Dinner (Royal Victoria Hotel)

South Western—"*Future of Gas Shielded Welding*" by A. A. Smith (Radiant House, Bristol, 7.15 p.m.)

10th Jan.—Liverpool—"*Prefabricated Welding of Ships' Structures*" by J. W. Day (College of Technology, Byrom Street, 7.15 p.m.)

11th Jan. South London—"*Low Alloy Steel Welding*" by E. Freeth (54 Princes Gate, S.W.7., 7.30 p.m.)

12th Jan.—Eastern Counties—"*Electro-slag welding*" by A. M. Horsfield (Colchester Technical College, 7.30 p.m.)

13th Jan.—Birmingham—"*Designing for Brazing*" by J. H. Jones (Grand Hotel, Birmingham, 7.30 p.m.)

16th Jan.—Sheffield—"*Use of Welding in Chemical Plants in the U.K.A.E.A.*" by F. S. Dickinson. Joint meeting with the Rotherham College of Technology Engineering Society.

South Wales—"*Tubular Construction*" by R. G. Taylor (Technical College, Neath, 7.0 p.m.)

16th–20th Jan.—School of Welding Technology—Course D15/2, Brazing Technology and Design.

17th Jan.—Leeds—Open Discussion Night (Hotel Metropole, Leeds, 7.30 p.m.)

South Wales—"*Tubular Construction*" by R. G. Taylor (Tubewrights Ltd., Newport, 7.0 p.m.)

18th Jan. — East Midlands — Loughborough. Not yet finalized.

East of Scotland—"*Pipeline Welding*" by R. J. Wright (25 Charlotte Square, Edingurgh, 7.30 p.m.)

Preston—"*Fabrication and Brazing of Copper Pipes*" by G. F. Charge (Municipal College, Burnley, 7.15 p.m.)

West of Scotland—"*Welding and Design in the Fabrication of High Strength Steels*" by L. H. Liston (Institution of Engineers & Shipbuilders, 39 Elmbank Crescent, Glasgow C.2, 7.0 p.m.)

Wolverhampton — "*Construction and Erection of Maidenhead By-pass Thames Bridge*" by J. S. Allen (Wulfrunians Club, 7.30 p.m.)

19th Jan.—Southern Counties—Meeting with the Naval Architects and Marine Engineers.

25th Jan.—North London—"*Practical Aspects of CO_2 Welding*" by F. Collins (54 Princes Gate, S.W.7., 7.30 p.m.)

27th Jan.—Birmingham—"*The Structural Engineer in the Field of Atomic Energy*" by T. C. Waters (Joint Meeting with Institute Structural Engineers), College of Advanced Technology, Costa Green, Birmingham, 6.30 p.m.

30th–31st Jan.—School of Welding Technology—Course D32, Design for Welding in Thermoplastics

1st Feb. — Manchester — "*Electro-slag Welding*" by A. M. Horsfield (Reynolds Hall, College of Science and Technology, Manchester, 7.15 p.m.)

2nd Feb.—N. E. Tyneside—"*Gas Cutting*" by G. Sims-Davies (Mining Institute, Newcastle, 7.0 p.m.)

Institute of Welding—Paper on the all-welded Thames bridge at Maidenhead (54 Princes Gate, S.W.7., 6.30 p.m.)

6th Feb.—South Western—"*Use of Welding in Srructural Engineering*" by J. S. Allen (Stothert & Pitt's Canteen, Bath, 7.15 p.m.)

7th Feb.—North London (Slough Section)—"*Pipeline Welding*" by R. J. Wright (Lecture Room, Community Centre, Farnham Road, Slough, 7.30 p.m.)

8th Feb.—East Midlands—"*Economic Aspects of Various Fusion Welding Processes*" by W. D. Waller (Nottingham)

South London—"*The All-welded Maidenhead Bridge*" by G. Roberts (54 Princes Gate, S.W.7., 7.30 p.m.)

Current WELDING LITERATURE

Book Reviews
Additions to the Institute Library
Trade Publications

CONTENTS OF PERIODICALS RECEIVED

This section is intended to give a survey of the current welding literature received by the Institute of Welding Library. The contents lists are not exhaustive; only the main articles in welding journals are listed, and reprints from other journals and short notes are generally excluded. In addition, welding articles from other periodicals are listed. Abstracts of welding literature are given in the Bibliographical Bulletin of Welding and Allied Processes, *published by the International Institute of Welding, and details of this may be obtained from the Secretary of the Institute of Welding.*

Welding Journals

Automatic Welding (U.S.S.R., translated by the B.W.R.A.), 1960, January

Selection of method for producing large diameter welded pipe, B. E. Paton, S. L. Mandelberg, R. I. Lashkevich, and V. P. Markov (1–17)

Effects of ultrasonic oscillations on weld crystallisation in electro-slag welding, A. A. Erokhin, G. F. Balandin, and V. D. Kodolov (18–24)

Effects of ultrasonic oscillations on weld pool crystallisation in automatic welding, V. A. Lebiga (25–32)

Crystallisation cracks in the heat affected zone, S. V. Lashko-Avakyan, and N. F. Lashko (33–47)

Investigation of roller-spot welding thin sheet in 1Kh18N9T stainless steel, V. V. Gorskii and L. T. Babkin (48–58)

Some rules for the electrical processes occurring during flash butt welding, V. Ya. Khazov (59–70)

The effects of electro-slag process conditions on metal pool dimensions when melting heavy section electrodes, D. A. Dudko, I. N. Rublevskii and G. S. Tyagun-Belous (71–79)

Automatic submerged arc hardfacing of variable pitch hydraulic turbine blades with strip electrodes, F. A. Khomus'ko and B. A. Rabotnov (80–92)

Electro-slag butt welding rails, V. I. Svetlopolyanskii and M. I. Gryazev (93–96)

Problems in procedure for testing welded joints in aluminium rapidly for corrosion in nitric acid, D. M. Rabkin, L. N. Yagupol'skaya, V. D. Pokhodenko, and N. A. Langer (96–102)

A magnetic caterpillar type travelling welding machine, M. I. Razikov (103–108)

Investigation of welded joints by local micro-analysis, V. V. Bogdanova (109–112)

Cast iron pipes resistance welded, Yu. V. Skul'skii (112–113)

African Oxygen, 1960, vol. 5, June

Manually operated flame hardening burner (5)

Flame descaling of heavy transport wheels (6–7)

Flux in silver brazing (11–13, 16)

Welding aluminium to steel (16)

Canadian Welder, 1960, vol. 51, July

Plasma arc: new welding and cutting tool, P. Sherwood (7–8)

Canadian Welder's 1960 welding equipment and supplies directory, Product listing section (11–41)

Manufacturer-Distributor reference (42–51)

Trade names index (51–55)

Canadian Welder, 1960, vol. 51, August

Log barges all welded, E. Dunnett (8–9)

Soldering solves a problem, C. James (10)

Spray hardsurfacing gives 400% improvement (12)

New inspection method (14)

CO_2 purging removes hazard (16)

The importance in welding of ductility and tensile strength, A. A. Thomson (19)

Journal of the Japan Welding Society, 1960, vol. 29, June

A measurement of arc force in argonarc welding, Part 1, A. Uchida (15–20)

Some experiments concerning workability of Type 316L austenitic stainless steel, T. Yoshida and others (21–25)

On the chemical reactions in molten steel with CO_2–O_2 arc welding; Report 2, I. Masumoto (26–35)

Effects of alloying elements on notch toughness of basic weld metals; Report 3 (36–46)

Study on the phenomena of inert gas metal-arc welding by high-speed motion pictures; Report 2, I. Ukita and S. Nobuhara (47–51)

Some investigations regarding oxygen cutting; Report 2, K. Suitsu and T. Yasuda (52–59)

Journal of the Japan Welding Society, 1960, vol. 29, July

Some recent information on the influence of hydrogen on steel and weld metal, K. L. Zeyen (3–10)

Cooling time and cracking in the heat-affected zone of various steels, H. Sekiguchi and others (11–19)

Study on phenomena of inert gas metal arc welding by high speed motion pictures (Report 3), I. Ukita and S. Nobuhara (20–25)

Some investigations regarding oxygen cutting (Report 3), K. Suitsu and T. Yasuda (26–32)

Effect of alloying elements on notch toughness of basic weld metals (Report 4), H. Sakaki (33–38)

Gaseous compositions in weld metals of austenitic stainless steel, M. Okada and others (39–45)

Cooling time and brittleness of various steels submitted to welding (Report 4), H. Sekiguchi and others (46–52)

La Pratique du Soudage (Belgium), 1960, vol. 14, June–July

The reconstruction of large copper vessels (113–121)

Some construction details of welded material used in coal transport, J. Maton (122–123)

Determination of the nature of the coating (124–125)

La Pratique du Soudage (Belgium), 1960, vol. 14, August–September

Some stainless steel welded constructions, Part 2, M. Bail (133–135)

(*Philips'*) *Welding News* (Holland), 1960, No. 107, January

Arc welding electrodes and their applications (6–14)

Stainless steels and their properties (15–16)

(*Philips'*) *Welding News* (Holland), 1960, No. 108, February

Carbon-dioxide welding of railway-wagon buffers, J. Lynch (2–5)

Secure insulating materials by means of stud welding, J. A. N. Clevers (6–7)

Industry looks to the processes that makes welding easier, A. H. Mulder (13–14)

Know-how in CO_2 welding, J. W. A. Stemerdink (14–16)

Przeglad Spawalnictwa (Poland), 1960, vol. 12, September

Some remarks on correlation of longitudinal and transversal fillet welds, R. Brzozowski and S. Jastrzebski

Trends in welding development in shipbuilding industry, E. Bargiel

Repair of cast iron gearing casing by welding, L. Dreher

Przeglad Spawalnictwa (Poland), 1960, vol. 12, October

Welding aspects of brittle fracture, R. Weck

Tests of electrodes suitability for the construction of welded ship hulls, M. Mysliwiec and Z. Poniewierski

Impact tests at low temperatures, E. A. Juffy

Schweissen und Schneiden (Germany), 1960, vol. 12, August

The Institutes for teaching and research in welding; centres of welding training and research in Germany, H. von Hofe (338–345)

Developments in CO_2 welding with grooved wire, C. De Rop and H. Schmidt-Bach (345–349)

Influence of impurities in carbon dioxide during inert gas welding, Tin Ming Wu (350–354)

Investigations into the electro-slag welding process, R. Muller (354–368)

Schweissen und Schneiden (Germany), 1960, vol. 12, September

Welding technique and economical production course, O. Lay (396–403)

The importance of welding-technique for the German Federal Railways, C. Stieler (404–408)

Electric welding apparatus 1959—economic details, A. Gese (409–412)

Economy of welding-technical processes in the new production and repair of agricultural vehicles, H. Wirtz (413–415)

Schweisstechnik (Austria), 1960, vol. 14, March

Resistance, spot and seam welding of aluminium alloys, E. A. Otto (25–30)

Notable advances in welding technique in Austria, A. Schmidt (31–33)

Schweisstechnik (Germany), 1960, vol. 10, July

Status of automatic welding processes in the German Democratic Republic, E. Luder (241–242)

Technical problems associated with the application of high productivity welding methods in conveyer line production, W. Anders (243–251)

Economic welding processes for assembly line production of welded vehicle sections, W. Zwingmann (254–259)

Soudage et Techniques Connexes (France), 1960, vol. 14, July/August

Welding in the U.S.S.R.—Report by the French Mission on Welding in the Soviet Union. November, 1959 (249–266)

Welding day at Metz: Part 1, Chemical composition and weldability, A. Leroy (269–276). **Part 2, Remarks on weldability tests,** H. Granjon and A. Audige (276–282)

Welding and allied processes in the maintenance departments of the French National Railway Company, R. Biais and P. Gauthier (311–320)

Welding and Metal Fabrication, 1960, vol. 28, August

Aspects of reactor fuel element fabrication, J. G. Purchas and H. R. W. Cobb (302–308)

Automatic welding of large storage tanks: applications of new CO_2 site welding equipment (309–315)

Saving weight with steel, B. Mitchell (316–318)

Fabricated cranes, D. M. Potter (319–324)

High strength bolting, H. Martin (325–329)

New factory for welding rods (330–332)

Welding and Metal Fabrication, 1960, vol. 28, September

Fabrication of height-finding radar equipment, C. Waller and E. Morley (340–346)

The practical application of electroslag welding, B. Kjellberg (347–356)

An 18 MeV mobile betatron, W. H. Laws and others (357–361)

The structure and properties of flash-butt welds in Nimonic 75, 80A and 90, F. A. Ball and D. R. Thorneycroft (362–367)

Argon-arc spot welding of commercial purity aluminium, L. M. Gourd and F. W. Copleston (368–374)

Welding Engineer (U.S.A.), 1960, vol. 45, July

How to connect aluminium welding cable, C. G. Sorflaten and R. A. Burkhardt (25–27)

Quality control can be easy and accurate with careful preparation, H. K. Eitelman (28–30)

Big boom used to fabricate nuclear unit (31)

Steel, aware of its competition, pleads its own case (32–33)

Medium frequency induction heating provides precise heat control, mobility for stress relieving, W. K. Haessler (34–36)

Mig, Tig welding builds aluminium mine cars (37)

Tig welding efficiency on reactor fuel elements upped from 99·75%, S. Donelson (40, 42)

AEC experiments with ultrasonics to join fuel elements (41)

All-welded pipeline replaces wooden aqueduct, C. W. Lytton (46, 48)

Hardness conversion chart. Engineering Data Sheet No. 239 (55)

Welding Engineer (U.S.A.), 1960, vol. 45, August

How to educate for welding, R. B. McCauley and others (33–35)

Manufacturer's school provides industry with all-round welders, H. B. Carey (36–38)

Industry lends a hand, establishes a college with a welding engineer course, M. D. Thomas (39)

Universities de-emphasize oxyacetylene courses, L. L. McBurney and M. E. Fallek (40)

One distributor carries customer service into welding education, H. Phelps (41)

Welding lends the oil industry a hand in vessel construction, D. S. Reichle and S. J. Buell (42–43)

Automatic CO_2-Mig welding increases heat exchanger production up to 65% (44–45)

Stainless steel is easily welded, R. J. Franz (46, 48, 50)

Stainless transit cars are resistance welded (58, 60)

Estimating costs for manual oxy-acetylene welding (63)

Welding Fabrication and Design (Australia), 1960, vol. 3, July

Fracture appearance of impact specimens taken from ship plates, J. A. Bennett (7–10)

Giant double toggle crusher for R.A.A.F. (12–13)

The future belongs to welding, B. Paton (14–16)

Retreading a dredge pump with tough alloy (17)

Welding Journal (U.S.A.), 1960, vol. 39, June

Conception, design and fabrication of a welded rigid-frame railroad bridge, R. T. Blewitt and others (577–583)

Specific problems associated with oxygen cutting of bevels, G. R. Spies (584–591)

Multiple brazing process, G. D. Cremer and R. S. Mueller (592–599)

Micro-wire welding, H. J. Orr and J. H. Headapohl (600–605)

Natural-gas cutting used in fabrication of pipes, L. H. Paines and H. Cutler (606)

Production in modern railroading. . . . High-iron heavyweights, C. R. Strutz and E. D. Uecker (607–609)

The science of arc welding; Part III. What the arc does.(1959 Adams Lecture), C. E. Jackson (225s–230s)

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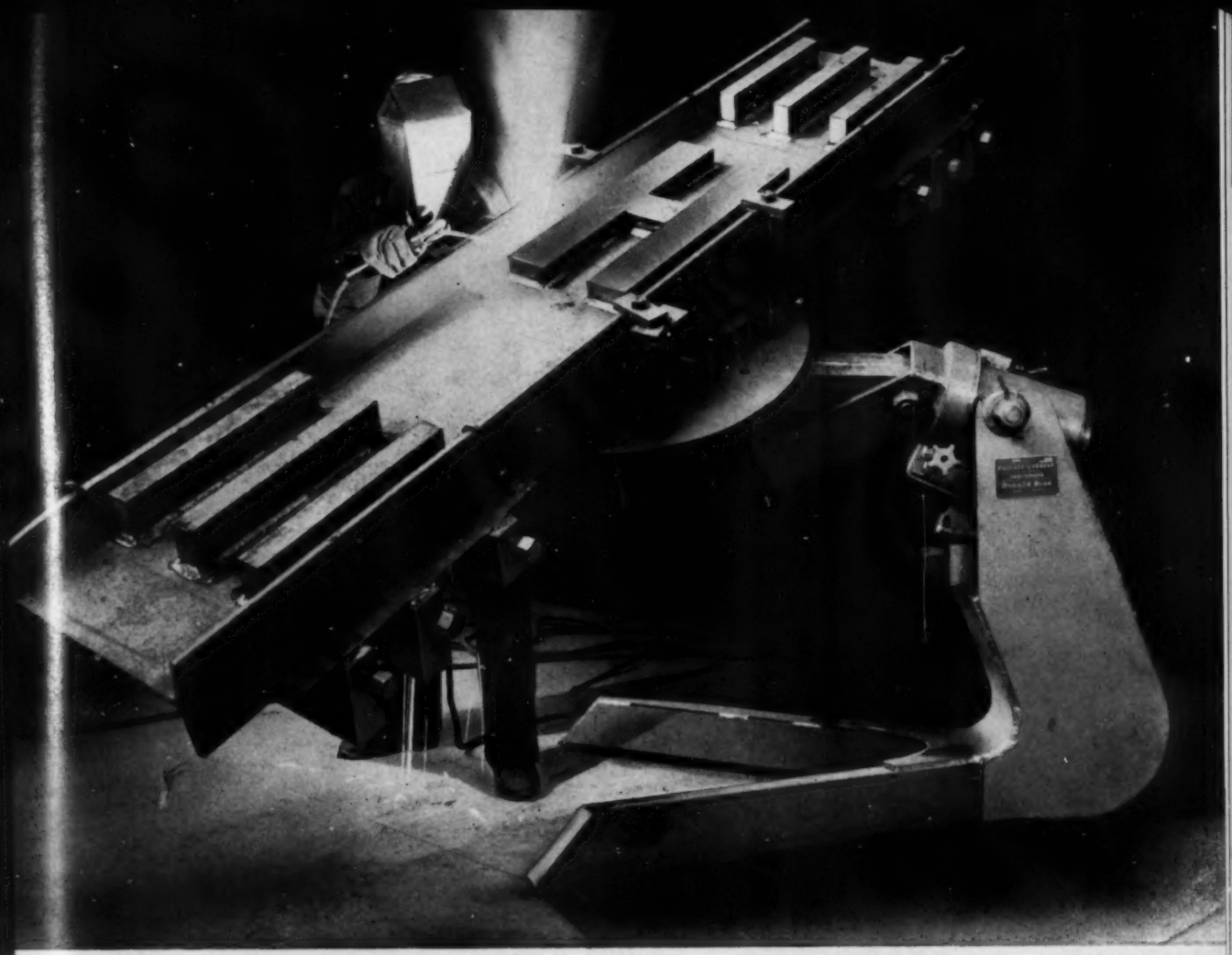

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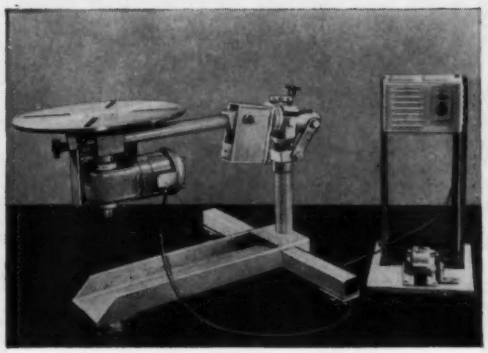

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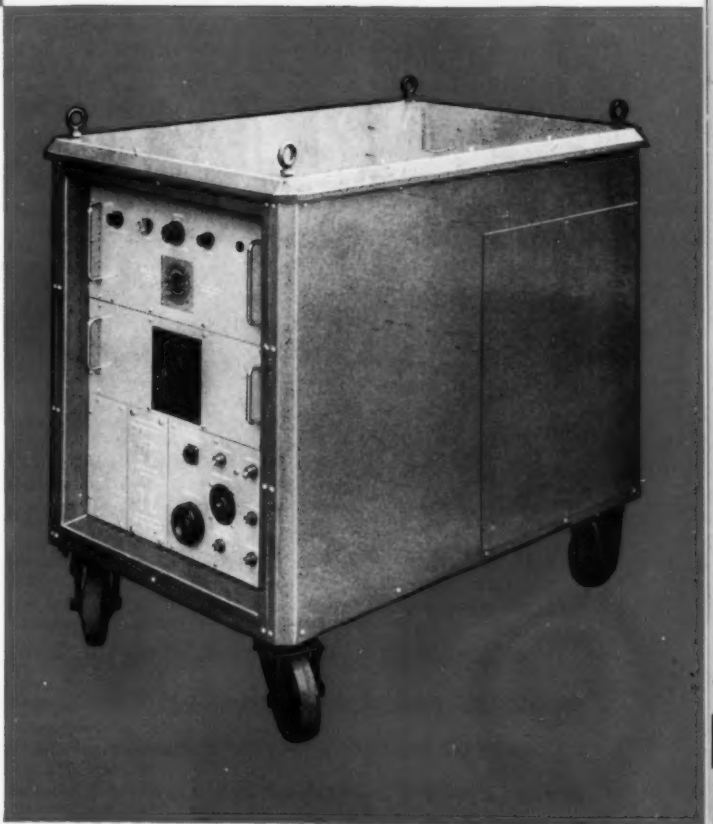

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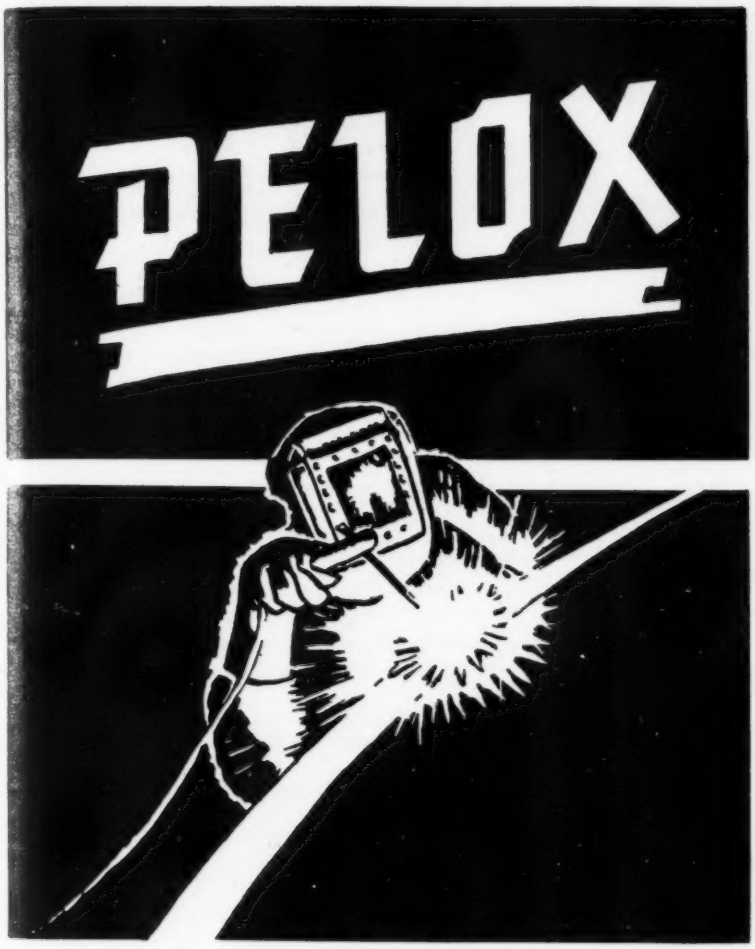

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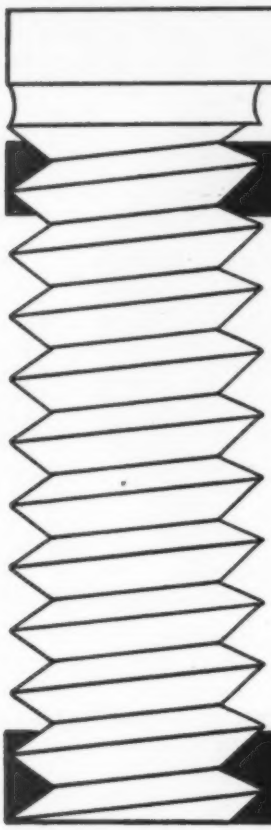

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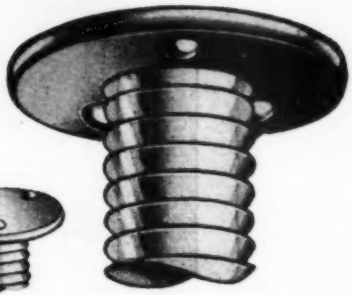

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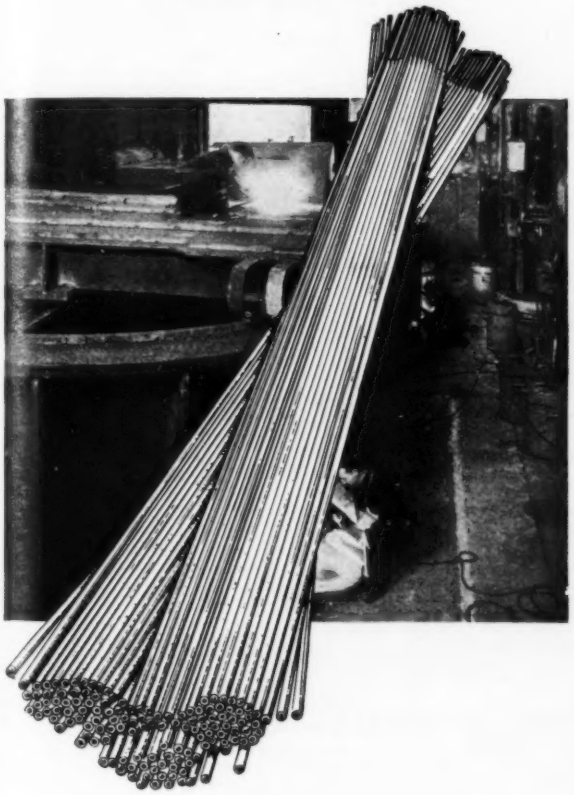

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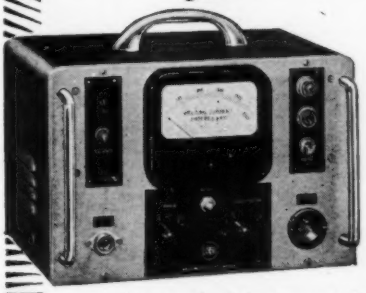

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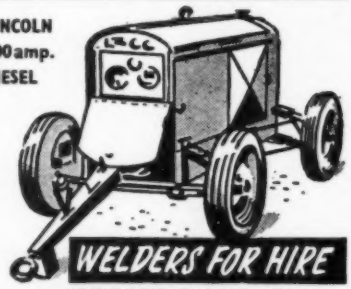

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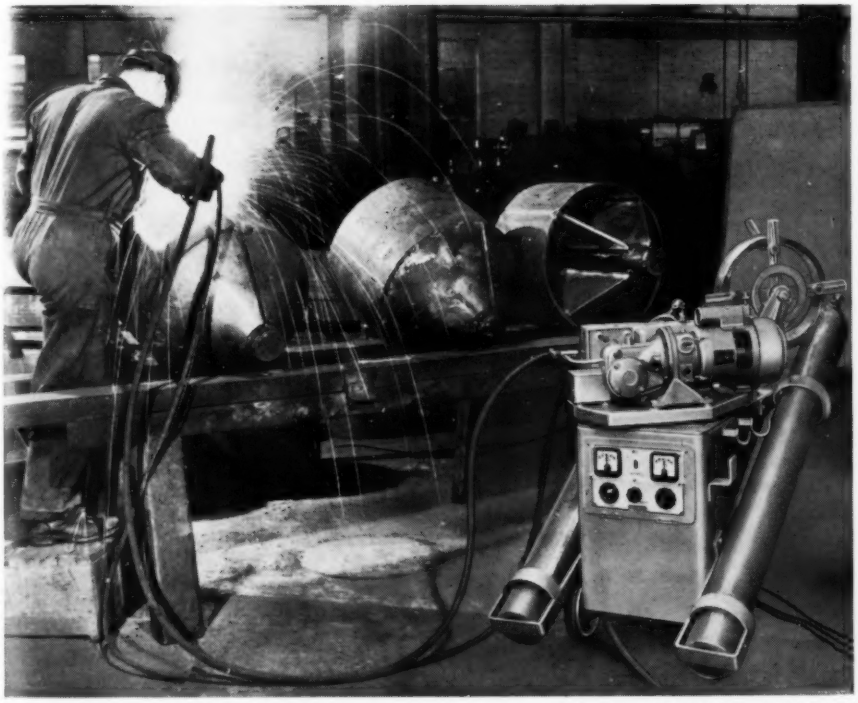

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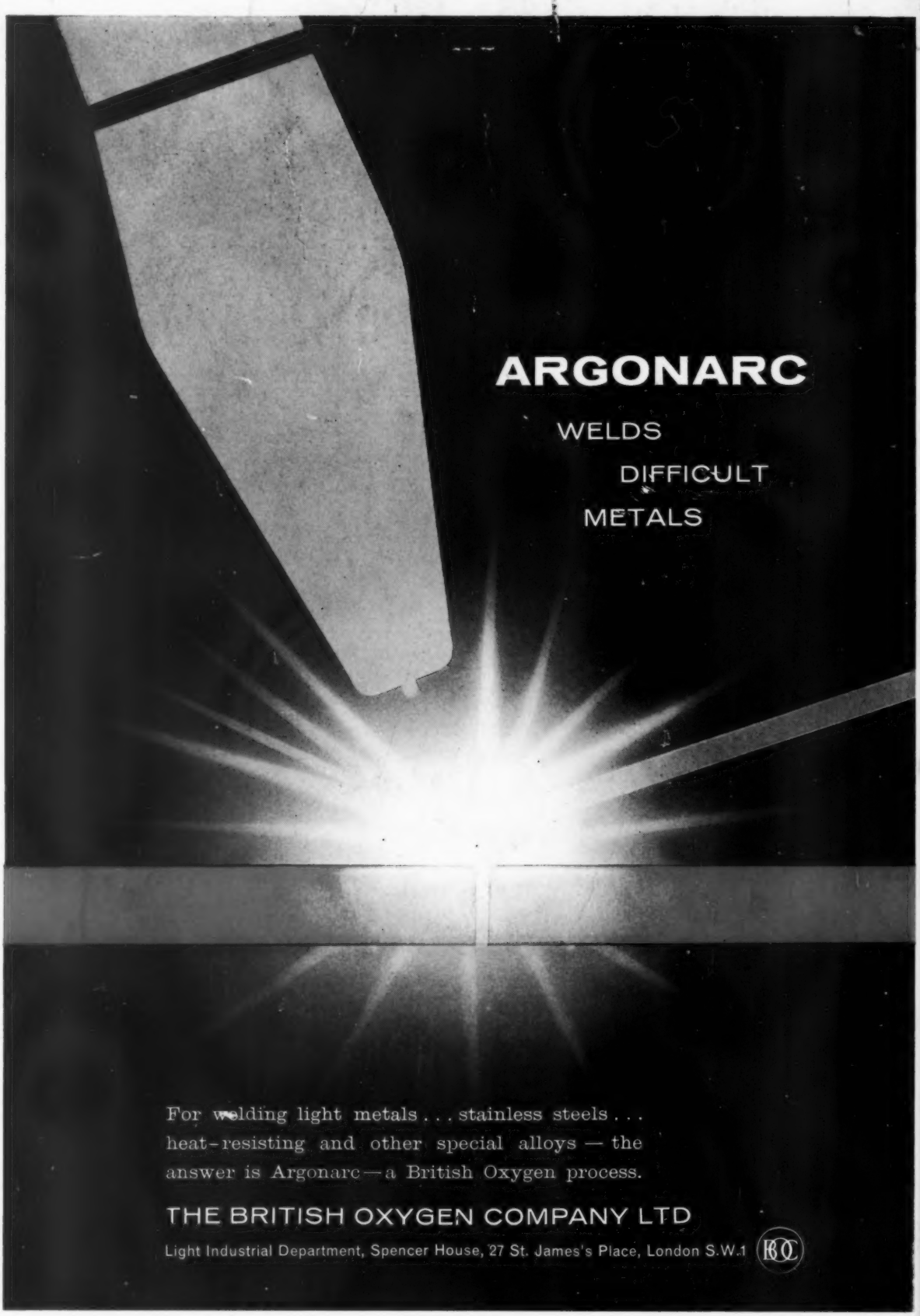
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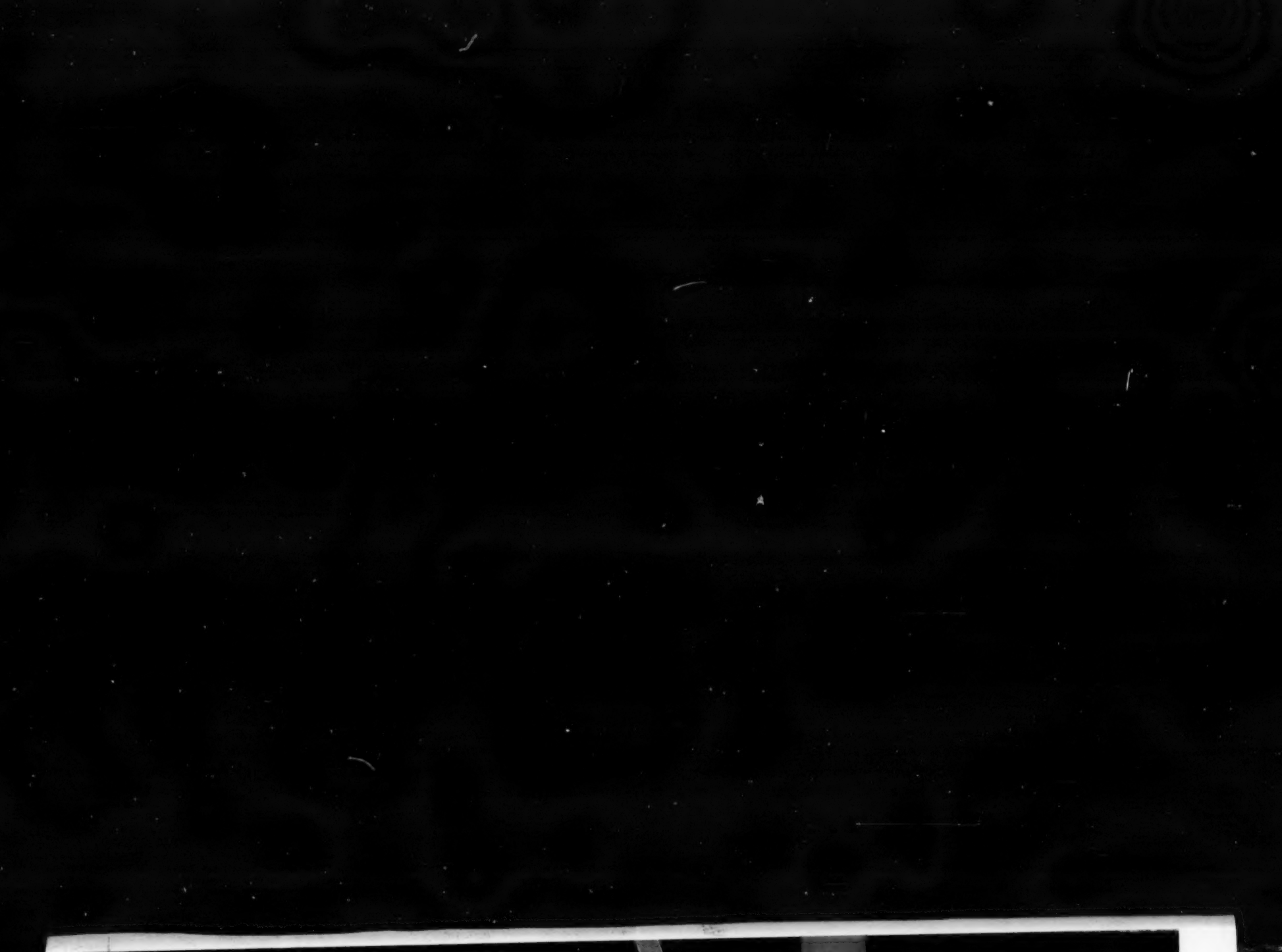
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